SUPPORTING THE DESIGN PROCESS OF DISTRIBUTED AND COLLOCATED MULTIDISCIPLINARY DESIGN TEAMS THROUGH TAG AND THUMBNAIL-BASED ORGANIZATION OF DESIGN DOCUMENTS

A Thesis
Presented to
The Academic Faculty

by

Natasha Powell

In Partial Fulfillment
of the Requirements for the Degree
Industrial Design in the
School of Architecture

Georgia Institute of Technology
December 2010

SUPPORTING THE DESIGN PROCESS OF DISTRIBUTED AND COLLOCATED MULTIDISCIPLINARY DESIGN TEAMS THROUGH TAG AND THUMBNAIL-BASED ORGANIZATION OF DESIGN DOCUMENTS

Approved by:

Dr. Jon Sanford, Advisor
School of Industrial Design
Georgia Institute of Technology

Dr. Claudia Winegarden
School of Industrial Design
Georgia Institute of Technology

Dr. Ali Mazalek
School of LCC
Georgia Institute of Technology

Date Approved: August 20, 2010

ACKNOWLEDGEMENTS

I'd like to thank my thesis committee; Jon Sanford, Ali Mazalek and Claudia Winegarden. I would also like to thank Karen Milchus for her beneficial feedback though it was unrequired. I'd like to thank Tina for her encouraging words and useful comments, Paul for his helpful and unique perspective, Erika, Jon and DJ for their support and help with my pilot studies, Richard for such useful comments while sitting through defense practice, and finally Pete for reviewing the review and the good luck Orangina.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

SUMMARY

In the multidisciplinary design process, design documents are used to help support a team's design and mediate any misunderstandings that occur. Current methods of organizing such design documents are either difficult to keep up to date physically with their digital versions, or inhibit distributed users access to important comparative information. Digital tag and content thumbnail-based document organization is presented as a possible alternative. The effects of tag-based document organization on the manner in which collocated and distributed design teams categorize, review and search design documents and resolve design misunderstandings were compared to the effects of traditional physical (the pin up walls of project rooms) & digital (shared digital file folders) document organization. Student participant design teams were assembled. These teams were observed organizing a provided set of design documents and develop a design solution as a team using either tag-based or traditional physical or digital document organization. Team members were given retrieval tests to compare search times between methods of document organization. User feedback on organization preferences were collected and used to develop a conceptual prototype of a document organization interface supportive of the multidisciplinary design process. Though the quantitative results did no clearly favor tag-based organization, observational results and user comments were in support of the capabilities tag-based organization provides.

CHAPTER 1

INTRODUCTION

The ability to retrieve, browse, and analyze previous iterations of collaborative work or other design documents is essential to good communication among members of multidisciplinary design teams. Without this ability, misunderstandings due to different problem solving approaches by team members can negatively affect cost and quality of a final design. As design team members refine discrepancies in their individual design contributions to better complement their team's final product, design conflicts or misunderstandings will often occur (Baskin, Kovács et al. 1999). To overcome misunderstandings, design teams return to their design documents to help to clarify the rationale behind on design decisions. Traditional methods of sorting design documents fall short in supporting behaviors that are common in the design process: reviewing multiple perspectives for analyzing documents and using highly visual methods of search for physically distributed teams. A collocated design team (a design team made up of members who share a location), as a standard of practice, will use physical project rooms to organize and group images, documents and post-it notes into a project history and informative groups upon pin up boards or walls. These spaces allow large scale visual analysis of multiple design documents. However, the physical documents and pertinent information from their organization displayed on these project walls are less accessible by distributed team members. Distributed teams, composed of members in different physical locations, will typically share electronic versions (i.e. files) of the pertinent design documents. Although files are organized within folder-based storage system searching for online documents, comparing multiple types of documents and searching for documents by recalling the precise date or file name of the desired documents within this method organization is time consuming and cumbersome for distributed design teams.

In contrast to physical pin up walls and electronic folder organization systems, digital tag-based document organization uses independent terms to associate with an object, allowing that object be freely organized within multiple categories. This flexibility in categorization is not possible while using file folder-based organization where folder hierarchy restricts multiple categorizations of files. To apply a file to multiple folder categories, users would then have to make copies or shortcuts: virtual references to a file in its original location. Content thumbnails, when applied with tag-based organization, allow for visual analysis of documents in a manner similar to that of physical project rooms. This file representation method also allows participants to also find documents more quickly by being less dependent upon file name and modification date (text-based search) and allowing the user to perform a visual search. These thumbnails are small digital images taken from the content of the document. The content thumbnail is then used to represent the document. For example, the miniaturized image of the first page of a word document would be the document's content thumbnail.

The purpose of this project was to compare the effects of tag-based and traditional digital and physical design document organization on the manner in which collocated and distributed design teams organize, review and search for design documents that are used to resolve design misunderstandings. Specifically, the study compared the design teams' use of traditional physical or digital methods (i.e. post/pin up wall and shared remote digital file folder systems) to the use of Adobe Bridge, a media organizing software which has contextual tagging capabilities for document organization. The experimental tag-based organizing teams were predicted to deliver improved design results; faster document retrieval times and better resolution of design misunderstandings. Additionally, qualitative observations and feedback from teams were used to develop design criteria. These criteria guided recommendations for the design of a organizing interface for design team use. A conceptual (i.e. non-functioning) prototype of the tag-based organization interface was designed for use by both co-located and distributed multidisciplinary teams. Such a system could be used to improve the quality and reduce the cost of final designs by improving co-located and distributed multidisciplinary design teams' ability to resolve misunderstandings through flexible grouping, retrieval and analysis of various design documents earlier than by the use of current traditional and digital means.

CHAPTER 2

LITERATURE REVIEW

Multidisciplinary Design Teams: Collocated and Distributed

The input of many disciplines is required in the successful design of consumer and commercial products. The efforts of hardware and software engineers, interface designers, and marketers all go into the creation of the average cell phone. The teams that create jets for commercial airlines include mechanical engineers, aerospace engineers and even interior designers. For both of these products, the experts that compose these multidisciplinary design teams must manage detailed information from a variety of fields and combine the important aspects of these divergent details into a jointly developed final product.

Due to economic factors like globalization, these design teams are more frequently becoming made up of team members in other countries (Li 2007). Though these teams can be composed of the best experts worldwide, the physical and social separation of these team members can support the creation of conflict in the design process. Due to the nature of these teams, conflicts that can occur can often go "unaddressed longer than conflicts in collocated teams" (Hinds and Bailey 2003). Hinds explains that this is due to the distance between the members and also the technology used to attempt to mediate this distance. These teams are prone to communicating less frequently due to the barriers that their communication technologies provide. Collocated teams, on the other hand, are more likely to initial even casual verbal communication. This style of verbal communication in association with sketches has been observed to be most likely to support "Aha" moments in the design process, in a multiple case study analysis of design student groups and design practitioners design processes (Jonson 2005).

Some studies believe that the best way to accommodate this distance is to have as many face-to-face meetings as possible, but this is not always a possibility (Busby 2001; Hinds and Bailey 2003). Such studies focus on the social aspects that are lacking in the design process as part of the reasons conflicts are more likely to occur, but sometimes the very nature of the technology used to mediate distance helps to prevent or diffuse emotional conflict. In Hinds and Bailey’s study on distributed teams, some team members would intentionally use email-based communication instead of video chatting or phones to avoid higher levels of emotional conflict. Whereas more studies focus on illicit aspects like emotional communication that are lacking in the distributed environment, fewer studies take a proactive view developing and evaluating current digital technologies’ ability to successfully support activities necessary for design.

Multidisciplinary Design Process: Joint Individual Designs into a Team Design

The nature of design conflict is not solely based upon the issues with technology. As a variety of disciplinary experts work together to design a product, they repeatedly fluctuate between their discipline-specific understanding of the design problem, and the joint understanding and requirements of the team. “As the design project develops, the part-whole relations are under constant interpretations by different team members from different design perspectives” (Peng 2001). Using the jet design example above, the interior designer must not only be aware of the details of interior features; but also that any changes to the body of the plane with regards to exterior air flow will affect his/her design space. During the design process, individuals’ ideas are assembled and eventually evolve into a team solution.

The multidisciplinary product design team must manage “complex system-level design problems that can only be solved by decomposing them into subsystems that generally have interaction constraints” (Baskin, Kovács et al. 1999). These interaction constraints are discovered or clarified during collaborative moments in the design process. At group meetings, web conferences or teleconferences, teams will evaluate individual design contributions to determine if they satisfy these interaction constraints. Team members will compare, contrast and seek patterns from the individual design ideas, to refine their design (Lai and Chang 2006). During the movement from individual, discipline-specific problem models to integrated, multidisciplinary problem models, each member repeatedly refines their individual designs to better fit the design problem as whole. The final design could be thought of as product of the team's attempt at a collective understanding of the design problem, and what they consider to be the best solution for the problem, resulting from the comparisons, contrasts and pattern seeking activities that occur around conflicts in the design process.

Conflict and Misunderstanding in the Multidisciplinary Design Process

The very nature of moving from individual models to a collective model creates conflict. "Forming separate sub-problems enables work to be processed in separate areas in parallel, but gives rise to conflict and rework because differing approaches to the overall problem may be implicit in each of the sub-systems"(Baskin, Kovács et al. 1999). These differences in approach are based upon their discipline specific training, causing these individuals to "frequently employ differing specialized vocabularies and ways for structuring the [design] solution" (Baskin, Kovács et al. 1999). Even as efforts are made to clearly communicate individual solutions to one another, the team members are not always able to predict these differences or if major conflicts will result from them. Their expertise also causes such issues to go unnoticed. These conflicts can have negative effects if not managed in a timely manner. Collaborative efforts can be set back by these conflicts. "For these reasons integrating the component solutions and solving the resulting conflicts frequently consumes much of the productivity that resulted from the concurrent design activity"(Baskin, Kovács et al. 1999). Such conflicts are often amplified for physically distributed multidisciplinary design teams. More recently, many design teams are being composed of members of different countries. This distributed work context adds an additional boundary hindering the benefits of design collaboration and breeding conflict also based on each country's cultural differences.

Conflicts are opportunities to reevaluate each other's problem models, open dialogue and search for alternate solutions. If conflicts go unnoticed or bad assumptions are made because of them, the misunderstandings that result can cause major issues in the design process, including expensive delays in production. Revisiting the cell phone design example mentioned earlier; let's propose that the interface designer left an interaction feature unspecified and the software engineer creates her own solution based on an assumption to cover this lack of information. Without proper communication and resolution, that assumption could later cause hardware compatibility conflict, like hardware overheating, that ends up being more costly to fix when noticed by manufacturing/hardware engineer later on in the design process or worse later on as a product recall when the product is already in the consumer market.

After interviews from members of various design teams, Busby found that for errors related to person to person interaction and person to design interaction common sources emerged: not understanding how changes in their design will affect others, not understanding the rationale behind or history of others' design decisions and not understanding when exceptions or assumptions can be made (Busby 2001). These rational-based misunderstandings often occur when "participants [design team members] cannot agree upon how and where newly generated design parts or relations among existing and emerging parts (due to design integration) should be taken care of"(Peng 2001). For these types of errors, solutions are often nested within the design documents created throughout the span of the design process. The timely organization and evaluation activities centered around these design documents are then integral to the resolution of misunderstandings and therefore the design process.

Design Documents and Misunderstanding Resolution

After misunderstandings occur there are several approaches taken to move forward in the design process. The team will open dialogue to either come up with alternative solutions that resolve the misunderstanding or reduce its impact, or go back to information from earlier on in the process to redefine aspects of the design that lead to the issue (Li 2007). Meetings are often scheduled to present the rationale behind design decisions made. Individuals will use this time to make public their ideas for feedback and distribution to other team members (Peng 2001). During this period design documents are compared and created. The documents are externalizations team members' understanding of objectives, constraints, form, materials, and other design details (Hutchins 1995). These externalizations are used to mediate differences between individuals or groups in design, supporting discussion, negotiation and alteration of designs (Perry and Sanderson 1998).

If an individual's design isn't a successful match to team expectations, alternative suggestions are then presented to handle the conflict. This is defined by Peng as "competing"; "[when] the proposed design changes are deemed doubtful by some members . . . the proposal invites or provokes other members' design thinking and they may subsequently propose alternative design changes that may in effect compete with the earlier ones." Otherwise, Peng describes, a more time consuming method "backtracking" will occur; "[when] the designer who proposed changes has to drop the intended changes because some members cannot accept the outcomes or the implications of the proposed changes from their domain specific design perspectives." In this situation, misunderstandings are solved by going back to earlier individual designs and even preliminary research on the design problem in efforts to build an understanding of the design problem more complementary to the interconnected parts. "When two designers with different perspectives on the problem come together to resolve conflicts or solve interacting constraints, they must be able to understand the basic structure of each other's model" (Baskin, Kovács et al. 1999).

In order to support team discussions to resolve misunderstandings, team members need quick and intuitive access to past design documents to use as resources to support the communication of the rationale behind individual work and how it can be integrated into a team design. Documents representing individual mental models and rational (like sketches or renderings) of the design problem space (or the problem and the context that surrounds it) are compared for conflicts during collaborative moments like group meetings. These documents are then refined to better fit the needs of the team problem space. Peng believes that a central display space for evaluation of these documents is needed for such collaborative moments. Peng views this "communal visual space" as a place to support dialog that helps the team to find potential interconnections between disciplinary parts to form a concurrent design whole. This shared visual space often holds broadly defined initial design documents like sketches, results from brainstorming and photographs and rough observations from user research. The aforementioned interconnections are also the product of visual comparison and pattern finding activities that are common to the design process. Peng further describes how the shared visual display space once established, helps teams to create a language and design rules between team members of varying backgrounds to test designs against in order to predict any potential conflicts. The "communal visual space" described by Peng can take various forms, including a physical meeting space or virtual, computer-mediated spaces.

Storage and Organization of Design Documents

The Project Room: A Physical Meeting Space

Collocated teams typically create a physical semi-permanent shared space as a communal visual space. In a study of design team artifacts and their evolution in the design process, Lauche found that "objectifications that became central to the collaborative work were posted on walls and often transformed from a flipchart or sketch to an electronic document" (Lauche 2005). This "project room" holds the results of meetings, presentations, whiteboard logged discussions and more documentation along the walls and tables within a room. This project room document organization method has three primary benefits:

1. Visual search and retrieval of documents: If a document or the item looked for has a semi-permanent location that item is easier to find. The visual documents (i.e. images) arranged on the wall of such a room allows for the brain to perform parallel instead of serial search which is performed faster that text-based search. "Collaboration is aided both by the persistence of the design artifact, which supports asynchronous collaboration and constant awareness of the state of the project, as well as by the greater-than-human-sized space allowing multiple people to simultaneously view, discuss, and modify the artifact" (Klemmer, Newman et al. 2001).
2. Visual management of complex information spaces: Large workspaces permit the representation of large, complex information spaces without the loss of contextual, peripheral information. Visual searches of a selection of documents are faster than text-based searches because the brain can perform search faster in parallel (deRosa and Tkacz 1976).
3. Help to build common understanding: Teams in these rooms when meeting would constantly refer to, point at and compare documents in order to gain team understanding. "They appear to provide a common basis through which people with different skills and perspectives could gain a common understanding of the problems discussed" (Perry and Sanderson 1998).

Design teams when sharing documents in these central visualization areas would have a tendency to freely discuss, point to and annotate important parts of their design documents (Perry and Sanderson 1998). The project room does have drawbacks because the information stored in these project rooms must be maintained and shared outside of the project room manually. In a study of a design company, researchers found that before every design review meeting there would be a line of persons waiting to use the wide format printer. (Khan, Matejka et al. 2009) If there are any changes made in the digital replicas of design documents they must be make physical and updated in the project space. The physicality of the project room and its contents leads to tedious behaviors for sharing information as well. Perry found that if smaller scale drawings were to be shared during meetings they had to be prepared and copied for all participants in advance.

Klemmer describes how most of the useful information in project rooms is from the comparisons of the various documents “in the relationships between information chunks.” Because of this, links or annotations (like post it notes) will “often fall out of sync” if the documents need to be shifted around or re grouped. A common issue as well involves sharing such information outside of the project room. Perry mentions that the aggregation of such artifacts between organizations was more difficult to control, leading to misunderstanding and confusion (Perry and Sanderson 1998). In addition, the “paper only representations” common to this document storage method also leave remote team members out of the loop.

Experiments in Project Room Style Organization

Many design experiments, acknowledging the visual benefits of the project room (also sometimes called design studios), have tried to develop prototypes that focused on digitizing a certain feature or activity of the project room, like whiteboards and image collection

CABINET: Supporting Visual Search and Serendipity

The CABINET (Keller, Sleeswijk Visser et al. 2009) was an experimental system created to support browsing design documents both physically and digitally. There are two primary methods of search; directed search and browsing (Rorissa 2008). In the design process, browsing occurs frequently as a method for finding design inspiration as well as document retrieval. CABINET, a digital table-top interface, allowed designers to turn all their physical image collections into digital ones that they could arrange virtually with physical gestures. Though the individual designers found this very useful they felt uncomfortable sharing their digital collections with others, because others would rearrange the designers' images. This system, though excellent at managing physical visual information digitally, was poor at collaboration which is an integral part of most design processes. This method also was not made to support non visual design documents or team members of varying disciplines.

Build It: Combining Physical and Digital Artifacts for Enhanced Design Collaboration.

The Build it system was a collocated interaction design system developed explicitly for multidisciplinary use (Lauche 2005). Field observations, task analysis and results from user questioning were used to develop and test an experimental system that "support[s] co-located interaction between designers in engineering and architecture, and other stakeholders such as clients, operators, or inhabitants" (Lauche 2005). The tablet top-based system, based on activity theories perception of artifacts as tools for information transfer, used physical artifacts in combination with digital 3D interfaces in order to digitize collaborative aspects of the architectural design process. This system like the CABINET did not consider interactions with distributed collaborators.

Shared Design Space: Sharing Ideas via Augmented Tabletop

Also using a table top set up, Haller et al, created and tested an interface in order to digitally emulate the 2D dimensional sketching and feedback that occurs during the design process. Because "'there is limited support for digital tools where people can play with ideas in a free form manner", the system provides digital pens and tabletop with virtual documents that could be arranged or annotated with text and drawings (Haller, Brandl et al. 2006). There was no focus in this study on the interfaces distributed capabilities as the purpose of the study was to test the best ways to translate the more common physical gestures in design annotation digitally.

Toward the Digital Design Studio: Large Scale Interactive Display Walls

Instead of the using the tabletop metaphor, Kahn et al were inspired by the large pin up walls of automotive design studios. Focusing on face to face collaboration, the group felt that "the visual nature of the artifacts involved in design work call for unique interactions and many of the affordances provided by large displays" (Khan, Matejka et al. 2009). Unlike the aforementioned study, this particular one gave emphasis to supporting larger teams via the large digital display, but in doing so also neglected the ability to integrate distributed participants.

*Designers' Outpost: Digital Representation of Post-*it based Design Activities*

Klemmer, et al. developed the Designers Outpost in order to "support the transition from early [paper-based] representation to later electronic tools". In other words, the group wanted to support early mind mapping and general idea aggregation in a digital manner as opposed to traditional paper tools, i.e post it notes. This system combined paper post-it annotation creation and arrangement on a wall with digital capturing capabilities. This feature allowed the group to pursue their secondary goal of supporting collaboration with designers "at another location" (Klemmer, Everitt et al. 2008). While this study did handle the issue of distributed team members, the distributed members' roll was primarily passive as they could see changes being made to the interface but not make any changes, giving the distributed participants very little input in visual organization and analysis during their teams design process.

Very few of the experiments attempted to accommodate their digitized physical features for distributed teams or team members. The experiments focused mainly on only sharing and saving brainstorming documents like post-it idea aggregation that are used in earlier stages of the design process, as opposed to organizing and sharing combinations of design documents (i.e. sketches, design criteria, user research results) that can be referred to throughout various points in the design process.

Computer Mediated Organization Spaces

Distributed teams unable to acquire a shared physical space will rely on computer mediated methods of document organization. Although this method is easier for keeping documents up to date, this method has compatibility drawbacks when applied to the design process. Perry mentions that these technologies are lacking in the ability to link design documents to their roles in supporting communication and coordination in the design process, which often occurs through the comparison and discussion of said documents. Design documents/artifacts are multiform. Some are primarily textual, like research articles on new technologies that could be applied to the design of a new cell phone. Some are visual and don’t incorporate any text in them at all, like sketches or renderings. Others are a combination of text and visual elements, like presentations containing updates on a design’s progress.

The approach that is required for computer-based organization and search does not support the highly visual and comparative nature of certain design documents or the visually-based browsing and searching that is so useful in physical project rooms. Computer-based organization is primarily textual, where file and folder names are the primary methods of arranging documents, but this is not always natural for visual documents. “Unlike words and other linguistic entities, pictures or images are much fuzzier and subject to many different interpretations depending on who is watching” (Peng 2001). Not only does this make certain documents more difficult to organize but it hinders the creative aspects of the design process.

The linearly hierarchical nature of file folders also does not support simultaneous classification of documents (Quan 2003). The multidisciplinary design process is composed of many documents that must be exchanged and applied to multiple disciplines, which therefore could be classified in many ways. Project rooms cause information to be lost or become outdated when changes are made (Klemmer, Everitt et al. 2008). Returning to the cell phone example, if sketches various phone casings that were grouped to compare hand grips needed to now be compared for display size these images would have to manually duplicated or rearranged into folders related to display information. When an individual’s changing mental hierarchy for the documents they need to find differs from the folder hierarchy initially created, they’ll have difficulty finding the document their looking for even before attempting to make changes to the document organization. Quan mentions that the static hierarchy of folders requires the searcher to remember the “*ordered* sequence of topics and subtopics” though “the topics of interest during retrieval might be different from those [that came to mind] during organization.”

The hierarchical and chronological nature of computer-based file folder organization poorly supports design document search and retrieval. File folder organization supports time intensive sequential search; “the folder system, where the user must navigate through every parent folder in order to reach the leaf folder with the desired article” (Quan 2003). The interdisciplinary nature of the design process implies a need for a more flexible categorization of design documents than file folders currently provide.

Tag and Content Thumbnail Based Design Document Organization

During the design process, most of the time spent is on the individual expert addressing design issues from his/her perspective (Kvan 2000). Shorter collaborative moments are then used to compare and discuss various groups or categories of documents representing these perspectives and refine any conflicts within them. Reusing the cell phone example, a designer may want to compare documents for screen size as well as phone grip shape, comparing how they affect one another. The multidisciplinary design process requires design document organization that supports flexibility between differing individual thought processes and search requirements, along with those for the design team as a whole.

Tag Based Design Document Organization

A tag is a word or a phrase that is associated with or assigned to a resource for describing information (Hsieh, Stu et al. 2009). Currently, tags are most frequently used in organization for casual social web applications where larger groups of peers can facilitate categorizations of objects; like Flickr, a photo sharing site, or delicious.com, a social website bookmarking page. The primary benefit of tag-based organization is that documents can be organized in multiple structures simultaneously. Tag-based organization's multiple categorization capabilities are complementary to the organization of design documents which are inherently interrelated and multidisciplinary.

Useful for browsing as well as directed search, tag-based organization methods allow the users the choice to recover and or discover objects and information within a corpus of images, documents, or links. (Xu, Fu et al. 2006). Unlike other methods, tag-based organization allows for its users to browse a large body of documents from a variety of perspectives (Quan 2003). This implies that the simultaneous categorization feature of this system would support the "differing specialized vocabularies and ways for structuring the [design] solution" (Baskin, Kovács et al. 1999) of team members very well. This feature was found, in a non-design search study with 21 participants, “to have shorter retrieval time and a better user experience than other works ” (Quan 2003). As often is the case in the design process, tag-based organization could support design processes where little is already known about the design topic. “Multiple categorization was reported to be more robust in situations where the topic space was initially unfamiliar or rapidly evolving” (Quan 2003).

Non- hierarchical tag-based organization has its drawbacks in some search applications: “Unlike a keyword-based search, wherein the seeker cannot be sure that a query has returned all relevant items, a folder hierarchy assures the seeker that all the files it contains are in one stable place” (Golder and Huberman 2006). Golder also noted that tag consistency is a common problem when tags must be shared amongst groups of people; “for example, items about television may be tagged either television or TV. This problem is compounded in a collaborative system, where all taggers either need to widely agree on a convention, or else accept that they must issue multiple or more complex queries to cover many possibilities. Synonymy is a significant problem because it is impossible to know how many items ‘out there’ one would have liked one’s query to have retrieved, but it did not.” These analyses are based upon tag-based systems without hierarchical features, but tag-based systems with hierarchical features could potentially help with issues of synonymy.

Content Document Thumbnails

Content document thumbnails show a low resolution thumbnail image the contents of a document or image. This feature is available for most image organization systems, but the textual documents are currently not commonly provided the same level of visualization in organization systems. The standard is usually an icon for each type of text-based document, i.e. pdf, doc, etc.

Figure 2.1 Text vs Image digital Representation

The human visual system can process images more quickly than text (Paivio 1974). Most though, don’t translate this into the visual aspects of text documents. Although visual search of images is much faster, visual features of text documents can also help the document search process. In a study using website search, thumbnails of the contents of websites with high amounts of textual content had a positive effect on the search process even with years of training using text only-based search. Woodruff et. Al (2002) found that users, when performing website searches with this method of thumbnail representation, “consistently allow[ed] for quick and accurate judgments about which content pages contain the answer to the query. This is particularly interesting because study participants had developed strategies for using text summaries over a period of years and lacked corresponding experience with thumbnails.” Allowing for display of content thumbnails for both textual and visual documents could potentially allow for digital means of mapping the interconnected complex design spaces similarly to that capability in a design teams’ physical project room.

Summary

Successful design processes require design teams to evaluate and combine the varying perspectives on design problem solving of their many disciplined members into a common language and system of rules. In order to create these rules, teams need a central visual space to categorize and evaluate the design documents created by its members from an equally wide variety of categories as there are team perspectives.

Though the project room is best at supporting large scale visualization of the complex interactions of design document parts as a whole, the project room is susceptible to displaying outdated information if not constantly updated with its digital duplicates and also leaves distributed team members unable to share this space equally. Digitally shared file folders, though easy to keep up to date and share with distributed team members, are lacking in the visualization features project rooms provide. Both of these methods are fairly inefficient when used for search, retrieval and comparison of documents across multiple categories.

Existing experimental methods have focused either on digitizing simultaneous collaborative behaviors like sketching where teams are collocated, or simulating collocated design behaviors for distributed teams, like post it note and whiteboard notating. These methods either ignored distributed participants or did not consider integrating long term storage of the pertinent collaborative data resulting from these processes with the other shared design documents. Though collaborative activity is a part of the design process comparatively is not where a majority of the design process time is spent (Kvan 2000). The brief meetings are actually moments of coordination and evaluation used to direct designs toward team requirements. Tag-based document organization with content thumbnail visualization of design document files is proposed as an alternative in attempts to retain the visual benefits of project rooms and allow remote access through by digital file sharing with cross categorization capabilities. This would allow both collocated and distributed members to evaluate documents freely from many perspectives allowing design teams to make the most of their design time.

CHAPTER 3

METHODOLOGY

Introduction

A study was conducted to observe the effect of design document organization on the manner in which collocated and distributed design teams categorize, review and search for design documents and resolve design misunderstandings. Specifically, eight different student participant teams were given the same design scenario and misunderstanding, but with different methods for organizing and accessing design documents. The eight groups were each assigned to one of four different settings. The setting varied in their physical vicinity to one another and the tools used to organize their design documents:

1. Co-located (participants work together in the same room) using experimental tag-based document organization
2. Co-located using traditional document organization (pin up boards)
3. Distributed (each participant works in a separate room) using experimental tag-based document organization
4. Distributed using traditional document organization (shared digital file folders)

Quantitative performance on search tasks was collected as well as qualitative observation and user feedback from participants. The qualitative feedback was used to guide the design of a design doc organization system fit for multidisciplinary teams.

Research Design

A design context was created in order to observe and compare use of tag-based and traditional document organization during the design process. Teams composed of three students of three different majors were assembled to represent the multidisciplinary design team. Two of the students were actual participants. The third student was a research compatriot, planted in the team to ensure that a controlled misunderstanding would occur.

In order to get the teams to participate in a design activity, the teams were given a design problem and related images and documents and asked to design a solution within a two hour time period. The design problem was to create a wheeled device with no gears or chain drive to transport an older woman around a relatively flat town. Forty-two documents were provided to the participants. Fifteen of the documents were text and image documents where the content of the document contained text and images related to topics like creating kick bikes on your own, the best location for putting storage on the bikes.   Twenty-four of the documents were image only documents with pictures of various users on bikes and kickbikes and three of the documents were text only research documents related to users balancing on kickbikes, and the health benefits of certain features of kickbikes.

Though introduced to each group as a research participant, the compatriot was tasked to make sure the same misunderstanding occurred for every group. This misunderstanding was added to the teams' process to evaluate document review and misunderstandings in the design process. The compatriot was tasked to deemphasize a feature required in the design brief. That feature was the bike's ability to be stored in a small space. Although this is a specification in the design brief, only three of the forty-two provided documents present information related to storage <u>of</u> the device, as opposed to the twelve documents related to providing storage space <u>on</u> the device. The misunderstanding was considered solved and not to be argued by the compatriot when either of the other participants referenced any document supporting why the device needs to be able to store compactly.

Half of the teams were given their supporting design documents on computer with a tag-based document organization software; Adobe Bridge. Of the remaining teams, half were provided a computer with Windows Explorer (the default interface for organizing documents with in a Windows operating system) as document organization tool and the other half were provided a physical pin up board and printed documents to use as organizational tools. Teams were each given 30 minutes to evaluate and organize their documents into ether tag groups, physical pin up groupings, or digital file folders. To evaluate retrieval speed (i.e., time to retrieve design documents), teams were given retrieval tests and asked to find certain documents after completing the organization of the provided design documents.

The effects of physical vicinity on team members were also being evaluated; half of all teams were distributed teams; where each participant worked in separate rooms from each other. The remaining teams were collocated; all participants worked in the same room. The following four team settings were developed by varying vicinity and document organization:

1. Co-located (participants work together in the same room) using experimental tag-based document organization(using Adobe Bridge)
2. Co-located using traditional document organization (pin up boards)
3. Distributed (each participant works in a separate room) using experimental tag-based document organization

4. Distributed using traditional document organization (shared digital file folders)

While each team member performed the retrieval test and answered questions, the other participants were asked to create their own individual solution. Participants were to create individual designs in order to simulate unpredicted misunderstandings due to individual idea conflicts. After retrieval test questions were completed participants were asked questions on document organization user preferences on the following topics:

- Tag/Folder/Group creation
- Tag/Folder/Group application
- Tag/Folder/Group searching
- Search saving
- Additional Features useful to the design process

The aforementioned methods were taken to evaluate design document organization, search, and analysis in a simulated multidisciplinary design environment. Design teams of different majors were assembled and assigned to a design problem. These teams were then asked to organize design documents, find certain design documents and provide feedback discussing their preferences for document organization. Teams were deceived to believe that their third team member was also a participant, but the participant was actually a co-researcher tasked to cause a design conflict within their design process in order to evaluate the each team's performance.

Participant Sample

Sixteen Georgia Tech students (two for each group, each with different disciplinary training) were recruited to take part in the study. The recruited participants were Georgia Tech students who had at least two semesters of training in their major.

Participants were to have acquired enough training in their discipline to be versed in the problem solving methods, vocabulary and assumptions that were common to their major. Groups were assembled to have at least one participant with a design background and one participant with a technical or science background (i.e. engineering, computer science, and chemistry). The students were recruited from email groups, flyers, and word of mouth. Though group selection was not constrained by this, each participant's collaborative experience was recorded for its possible effects on his or her group's final design. The third member of each group was a research compatriot who was responsible for creating the same misunderstandings for each group during design development. His background in architecture was taken into account during the group selection process.

Experimental Environment

Once these groups were assembled, each team as selected to either work as a collocated (all participants work in the same room) or distributed team (each participant works in a separate room) and to either use a traditional document organization (physical pin up boards for the collocated teams; a digital file-folder system for the distributed team) or the experimental tag-based organization tool, Adobe Bridge.

The distributed environment: Each distributed participant was provided a separate room within the same research building. These rooms were each equipped with desk and Desktop PC equipped with a web-camera. A digital camera was tethered to this PC to quickly upload any drawings and sketches to share with their teammates. Paper and writing tools were also provided for sketch creation.

The collocated environment: The collocated teams were shared one desktop PC with a large widescreen monitor (around 25" diagonal). They were provided with an additional central table, paper and writing tools for developing ideas. Co-located teams assigned to traditional doc organization methods were provided physical documents, post it notes, pin-up boards and push pins.

Software: Regardless of their assignments, each group was provided with the same design software to develop a digital two dimensional representation of their design solutions; Adobe Illustrator and Photoshop, and Microsoft Office. All distributed teams were provided shared access to a remote folder with design documents within it. Teams assigned to work in a distributed environment also used Adobe Connect now to web conference with one another. Adobe Connect Now is an internet-based software with file sharing, digital whiteboard collaborative drawing, screen sharing, screen control sharing, and webcam conferencing capabilities. Teams assigned to the experimental tag-based organization used Adobe Bridge. This software, though designed for individual use and, allows its users to both hierarchically tag documents and view content thumbnails representing each document. Whereas other tag-based organization softwares provided single level-uniform tags, Bridge's hierarchical tagging capability was a primary reason for is selection as the surrogate tag-based organization software to be used in the study. Adobe Bridge was chosen as the surrogate tag-based organization software to run this study with functional software in order get more enriched observational results, as opposed to the use of an abstract nonfunctioning prototype with results that would be more hypothetical than practical. A screen shot of Adobe Bridge can be found in the Appendix. The distributed teams required to use traditional document organization methods used the Windows Explorer interface.

Variables

There were three primary forms of data that were collected from the study:

- Timing from retrieval tests
- Feedback from participants regarding organization preferences
- Observations from
  - misunderstandings, and
  - document grouping

Retrieval time was calculated as the time taken to retrieve a design document (i.e., the moment the solution document was clicked without moving immediately to a new document within seconds) from the time the task was given. After completing the retrieval tests, participants were asked open-ended questions to gain insight on their methods and preferences based on four topics related to tag-based organization; applying tags, searching for documents using tags, saving searches and additional features that would support the design process. The comments were transcribed into a text document and then compared for frequently occurring preferences and comments. The resulting topics were put into groups. Once the design teams began refining their designs, the observation notes were collected and reviewed for document search and review during design misunderstandings. After completion of the study, each teams grouping of documents was collected in a text document to be compared. The data was grouped such that comparisons ultimately could be made between the experimental tag-based and traditional document organization; as well as collocated and distributed design teams.

Experimental Procedure

Every team completes the study in three parts; Introduction and Software training, Design Document Organization and Retrieval, and finally, Group Design and

Misunderstanding Implementation. All distributed teams were trained on how to use web conferencing software (Adobe Connect Now), and all experimental organization groups were trained on how to use Adobe Bridge.

Introduction and Training:

During this portion participants were informed the purpose of the study was related to design document organization and design team performance. The groups were informed that they would be given a design problem and documents supporting the design problem. They were to organize these documents so that they could retrieve them as they design a solution. Additionally, they were instructed to not use any outside sources like the internet.

All distributed teams were trained on how to collaborate/communicate via Adobe Connect Now. The training included instructions on the following capabilities of Connect Now:

- File sharing
- Screen sharing
- Screen control sharing
- Webcam and microphone sharing

The co-located traditional document organization teams were not trained on document organization tools, but informed of the following resources available to organize their design documents: push pins, pin up boards, markers and post it notes. Distributed traditional teams were given a review on how to create folders, copy and move files from various locations, and how to use the search tool provided in Windows Explorer to search for files. Experimental document organization teams were provided training on Adobe Bridge. In order to build familiarity with organizing documents and searching for documents using tags, groups using Adobe Bridge were shown how to do the following:

- Create tags as a group
- Apply tags to files,
- Search for files using tags, and
- Save the tag searches they've created.

Once participants were trained on the pertinent software, they were then introduced to the design scenario. The script for introducing the design scenarios was fairly vague in order to support the misunderstanding that would occur further along in the study. The script only mentioned that the design solution "should be a wheeled device, designed for middle aged to older women, and further requirements like storage can be found in the design brief." The topic of the design brief was chosen in order to accommodate a variety of majors; a wheeled short distance transportation device, requiring no motors or chain drives. User behaviors and other user specific information were included in the brief to provide a context for the design solution.

The design brief was located in the same shared folder with all other design documents. During the introduction, participants were also informed that a template is provided for their final design document. Each group was required to deliver a final design document at the end of the study. This template was created so that design time need not be devoted the layout of this document. The remaining supporting design documents were of three varieties; text only, text and image, image only.

Of the forty-two total design documents, fifteen were hybrid documents containing text and images, twenty-four were images, and three were text only documents. The text and image documents included user reviews of bike storage types, and bike assembly directions. The images were a primarily a variety of users at various points of interaction with their bikes or kick bikes a few images showing details of a bike or kickbike's features. The text documents were science articles and anthropometric data related to the expected user.

Figure 3.1: Examples of text, image, and text/image documents used in study.

Document Organization and Retrieval Tests:

At the completion of the introduction and training (which took around 15mins), the groups were informed that they would be given 15 minutes to browse and create groupings to organize their documents in, and then additional 15 minutes to put their documents into these groups. After each of those time sessions was completed, the participants were given a total of 30mins to develop a design solution individually. The participants were asked to each develop their own solution in order to facilitate the occurrence of a misunderstanding during the next phase of the study. During this time, individuals were asked to retrieve three documents from the documents that were recently organized, as well as questions about their organization preferences.

During the retrieval tests, the participants were asked questions related to the design that required them to pull up the relevant information in a text only document, a text and image document, and an image. For example, the participants were asked to look up issues with handlebar bag storage for kick-bikes. The document with information on this topic has both images and text within it. The organization preference questions were regarding interface and interaction preferences for teams with experimental organization, and regarding organization method preferences for teams with traditional organization. These results were used to guide the design of a refined prototype of a design document organization interface for multidisciplinary design teams.

Design and Misunderstanding:

After each of the participants was interviewed, the group was then reassembled to complete their collective design. The teams were then given 45 minutes to discuss the designs they had created on their own and develop a single solution as a group. As the individual designs were presented to the group, the research compatriot implemented a misunderstanding by downplaying the importance of a feature that is mentioned in the design brief. That feature was the bike's ability to be stored in a small space. This misunderstanding was the same among all groups. Once a team member referenced a document that communicated the importance of this neglected feature, or the team agreed upon how to move forward with that feature the compatriot was not to instigate the misunderstanding any further. Once the group produced the final design document, they were given follow-up questions related to organization preferences, now in the context of a group design process.

Data Analysis

Screen capturing video software was the primary source of collected data. MORAE research software was used to capture video of each participant's screens and audio of their interactions. The MORAE remote viewer allowed the researcher simultaneous observation of the participants' computers and the audio from the group's discussion of their work. All participants' questioning was computer facilitated, so that the audio from interviews and retrieval tests were all captured along with the participants' design interactions.

The retrieval tests and interview questions were placed on a PowerPoint displayed from the interviewed participant's computer. The presentation was also used as a visual guide for video review/analysis and uniform participant questioning. Because the co-located traditional organization groups were not using computer-based resources to organize their documents, the researcher observed and noted organizing, searching and browsing behaviors via streaming video in a separate room.

Retrieval Tests

Retrieval time was calculated as the time between the end of the presentation of the retrieval question and the moment the solution document was clicked (in confidence, without moving immediately to a new document within seconds). Time measurements from the retrieval test were calculated using the marked time on the video time code from the MORAE screen captured video. The arithmetic mean and standard error of the document retrieval times was calculated from a data set of four values for each of the three document types (text and image, image only and text only) to determine if certain document types performed better in tag-based organization than others. Overall average values for the retrieval tests per the four design session types were also calculated out of a set of twelve values.

Document Organization and Analysis Observations

Observations recorded during each teams' design process were used to determine document organization's effects on design misunderstanding resolution and design document searching. Observational notes were taken on what document categorizations and behaviors were used to support the teams' decision-making during their design processes. Each team's hierarchy of tags, folders or physical document groupings was collected in a text document. Any attempts of traditional organization teams at cross categorizing documents were also noted. Whether the predicted misunderstanding or not, any topics or design features that needed to be compared were collected in observation notes. Such search and browse related observations were recorded during the entirety of the group design portion of the study as well. After all studies were completed, the recordings were reviewed along with the observational notes taken during the study. Additional observational notes were created from any missed information during recording review.

User Organization Preference Interviews

During review of the screen capture videos, the user comments from open ended questions were transcribed. The text was then searched for frequently mentioned subjects. Those subjects were then grouped into topics that were to guide the design criteria for the conceptual prototype.

CHAPTER 4

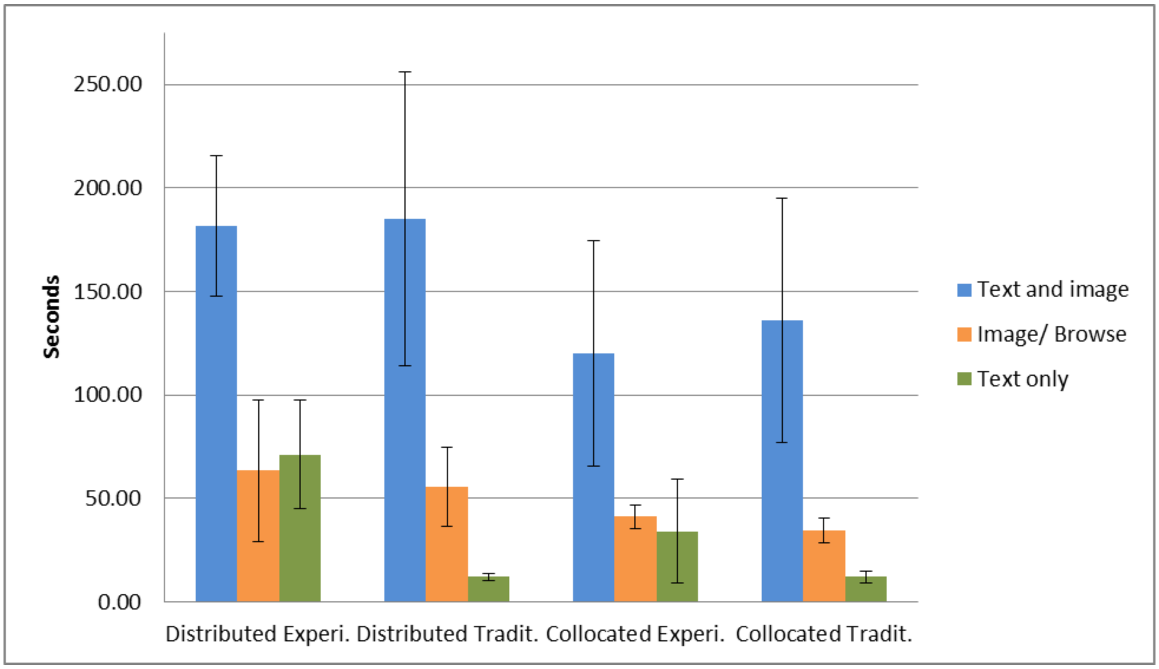
RESULTS

Quantitative time-based results were evaluated by comparing the mean of values and standard error from the document retrieval tests of participants using experimental organization methods to those of participants using traditional methods. The qualitative results were used to guide the design of a conceptual prototype.

Retrieval Tests

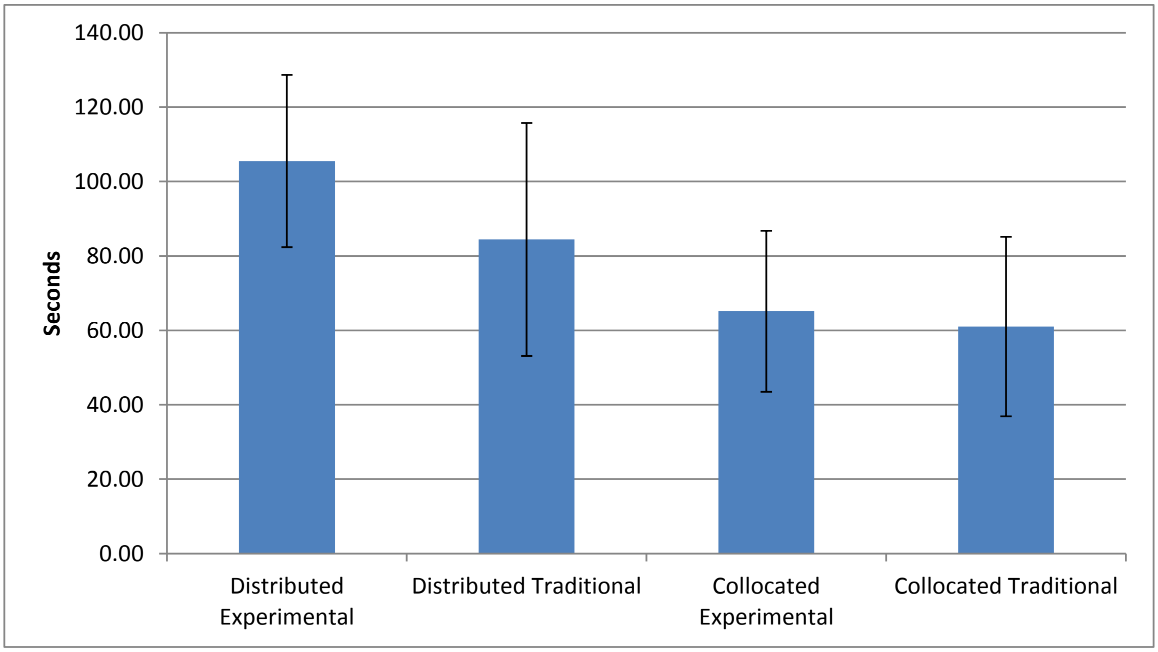
Table 4.1 shows the results of the retrieval tests based on specific document types. The height of each bar represents the mean of the total seconds for each document type and team type. The standard error of the mean for each set of retrieval times is shown as the error bar that extends from the time values. The time values that were returned for the text and image document retrieval tests were the highest of all the document types. The lowest average values were returned for the text only document retrieval tests.

Table 4.1: Document specific means of document retrieval tests.



250.00
200.00
150.00
100.00
50.00
0.00
Seconds
Distributed Experi.
Distributed Tradit.
Collocated Experi.
Collocated Tradit.
Text and image
Image/ Browse
Text only

Table 4.2: Overall means of document retrieval tests.



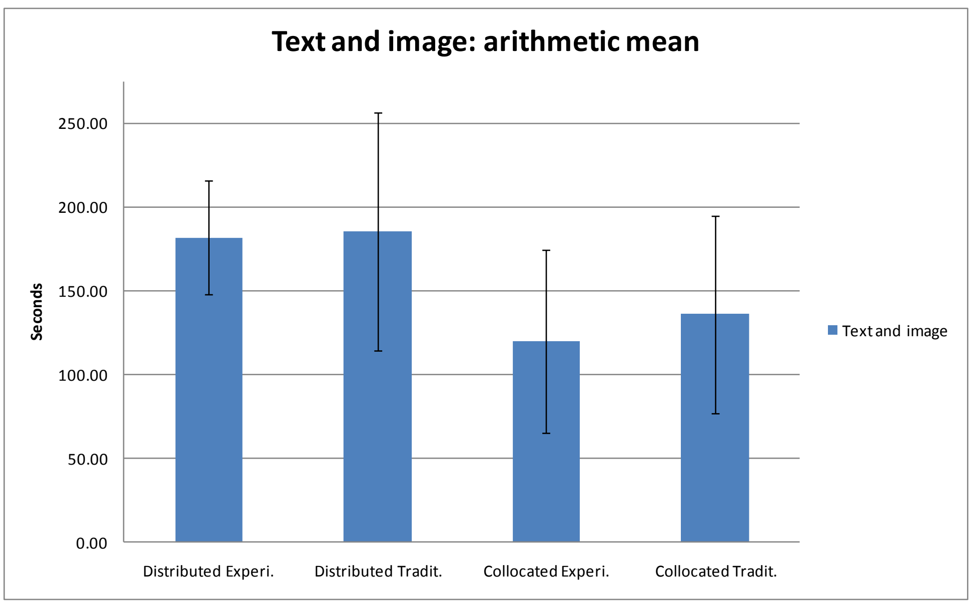
The comparisons between overall means were used to determine if distributed and experimental tag-based organization design teams would produce retrieval times comparable to collocated design teams and experimental retrieval times shorter than traditional retrieval times. The resultant time means were as follows Distributed Experimental 105. 5 seconds, Distributed Traditional 84.42 seconds, Collocated Experiment 65.17 seconds, Collocated Traditional 61.00 seconds. The experimental values were higher than the traditional values for both distributed and collocated teams. Table 4.2 shows the distributed teams' retrieval average was, at minimum, around twenty seconds longer than those of collocated teams. The mean value of the distributed experimental teams was about twenty seconds longer than the distributed traditional teams as well. The Collocated teams using the experimental tag-based organization method differed from their traditional counterparts by only five seconds. The largest error range or variance between values was found in the distributed traditional results. The overlapping standard error ranges of collocated traditional mean and the collated experimental mean imply there isn't a strong statistical significance to the difference between the values.

The document specific retrieval details shown in table 4.3, displays a slightly different result for the teams, than the overall averages.

Table 4.3: Document type specific mean values of document retrieval tests.

	Text and image	Image/ Browse	Text only
Distributed Experi.	181.75	63.5	71.25
Distributed Tradit.	185.25	55.75	12.25
Collocated Experi.	120	41.25	34.25
Collocated Tradit.	136	34.75	12.25

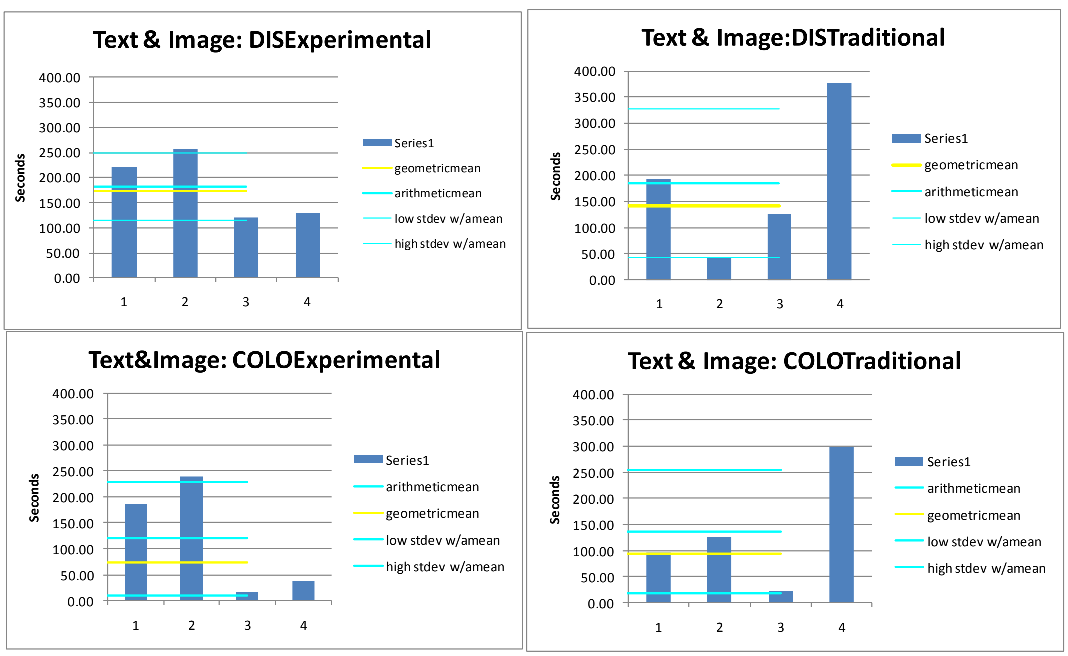
Table 4.4: Mean and standard error for text and image document retrieval tests



The experimental retrieval times were shorter than the traditional times in the text and image document retrieval tests. The specific retrieval means for the text and image document were 181.75 seconds for the distributed experimental teams, 185.25 seconds for distributed traditional teams, 120.00 seconds for collocated experimental teams, and 136.00 seconds for collocated traditional teams. The experimental retrieval values were a

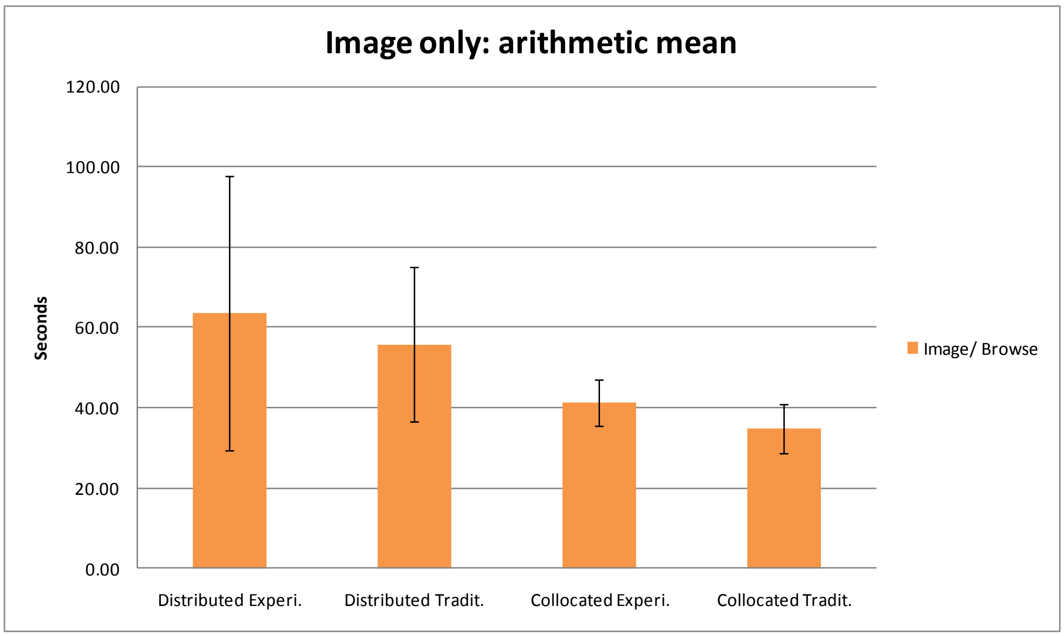
16 seconds shorter for collocated teams than traditional retrieval values.   For the distributed teams, the difference between the experimental and traditional means were not very large (3.5 seconds), and the standard error ranges shown in Table 4.4 suggests that this difference is not statistically significant. The large variances in values that resulted in such a wide error range, as seen in rightmost charts in Table 4.5, were related to factors that were evaluated qualitatively to provide situational/contextual meaning to the outlying values, like software malfunction and user error. Technical errors also occur in the actual design process, so those outlying the values were retained in the mean.

Table 4.5: Raw retrieval test results for text and image document



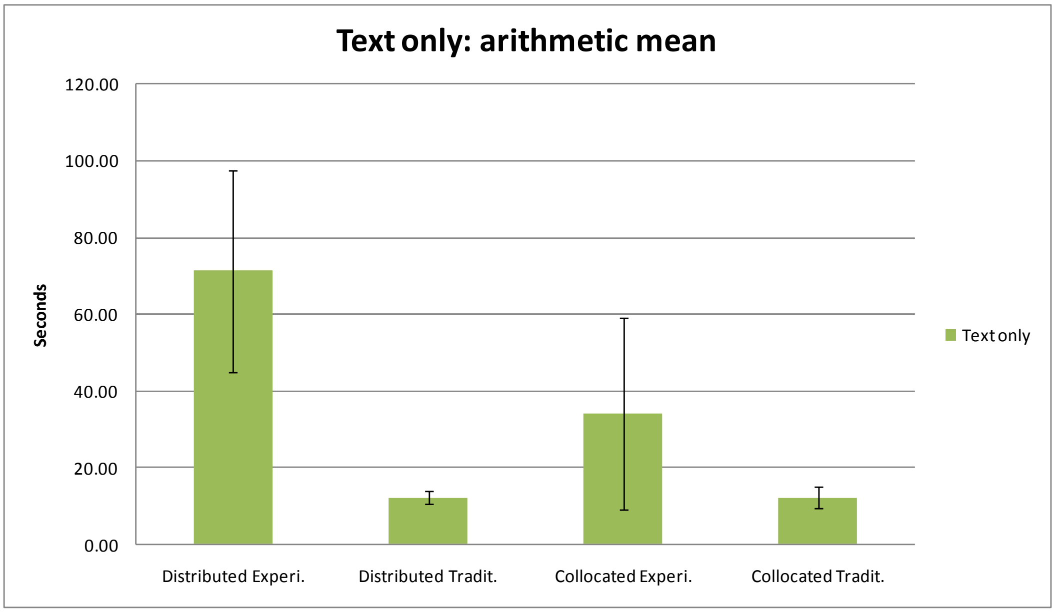
The image only retrieval test asked to participants to compare a specific group of images to find the correct image. Table 4.6 shows the mean and standard errors of each run. The mean values are as follows 63.50 seconds for the distributed experimental teams, 55.75 seconds for distributed traditional teams, 41.25 seconds for collocated experimental teams, and 34.75 seconds for collocated traditional teams. The experimental groups had retrieval averages a minimum of six seconds higher and a maximum of about twenty eight seconds than traditional groups. The distributed experimental mean was around seven seconds larger than the traditional mean. The collocated experimental mean was about six seconds larger than the traditional mean.

Table 4.6: Mean and standard error for image retrieval tests



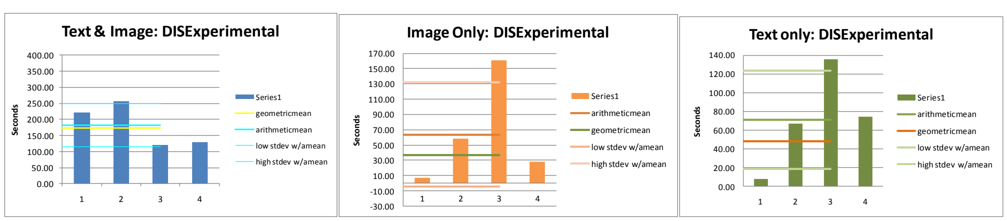
The shortest retrieval times overall were contributed to traditional teams and text only document, as shown in Table 4.7.   The specific retrieval means for the text only document were 71.25 seconds for the distributed experimental teams, 12.25 seconds for distributed traditional teams, 34.25 seconds for collocated experimental teams, and 12.25 seconds for collocated traditional teams. The experimental groups' retrieval averages were a minimum of 22 seconds longer and a maximum of 59 seconds than the traditional averages.

Table 4.7: Mean and standard error for text only document retrieval tests



With the study's small sample size, only 4 data points for each document test type, the statistical significance of differences in those results were difficult to validate. Investigation of the details surrounding the numerical results still provided valuable insights. Table 4.8 shows the resulting consistently higher values for participant 2 who had technical difficulties across all document retrieval types.

Table 4.8: Distributed experimental retrieval test values



Such disruptions were actually useful for qualitative analysis of performance in conditions that easily lead to misunderstandings in the design process. The timing values for resolving the planned misunderstanding weren't captured in this study. The prescribed points to begin and end timing for misunderstanding resolution were not always clear, and in many cases it was difficult for the co-researcher to implement the misunderstanding. In most circumstances, participants would keep the design brief open on the computer or pin up centrally as reference during the document organization and design portions of the study. This document had the clearest information related to the misunderstanding, therefore the participants would either clearly initially discuss the brief, preventing the co-researcher from legitimizing the misunderstanding, or when the co-researcher mentioned the misunderstanding they wouldn't need to search for the document as a helpful resource because it was already open on their desktops. Qualitative data from observations during unintended misunderstandings were collected instead.

Observations

Observational notes were grouped to compare how the following document management and search behaviors differed across the four design settings: creating groups of design documents, cross categorization of documents, document browsing and comparison. Results from open ended questions were also organized into groups based on frequency.

Document Grouping and Cross Categorization

Out of the eight teams, there were six topics that over half of the design teams used as primary tags or folders:

- Folding (5 of 8 teams)
- Research (5 of 8)
- Kickbike types (5 of 8)

- DIY/fabrication (5 of 8)
- Wheel quantity (6 out of 8)
- Storage (7 of 8)

Only a three (one collocated experimental team, one distributed experimental team, and one distributed traditional team) of the eight teams decided to create primary folders/tags/groups related to file type. These groups had two primary groups; Documents and Images. Sub groups were related to the content of these document types.

While all experimental teams freely applied multiple categorizations to their documents, the traditional teams also attempted some forms of cross categorization. The traditional teams were more likely to cross categorize the images of kickbike types in groups related to wheel number and storage type or wheel number and number seats. Teams using the traditional file folder-based system ended up duplicating the files into separate folder hierarchies to accommodate multiple categorizations. For example, images with four wheel kickbikes with storage were placed in a four wheel folder and also copied into a folder titled storage. Collocated traditional teams tried to pin up the files into nearby groups with similar headings. An example is shown here in Figure 4.9 where the team made a separate column for single kickbikes with space for cargo.

Figure 4.9: Collocated Traditional Cross-categorization Example

Document Comparison and Analysis

Observational notes on how teams use their organizing groups to browse and analysis documents to solve unpredicted design misunderstandings were collected. The team design and individual design creation portions of the study were reviewed and annotated. The results were as follows:

1. Collocated traditional teams browsed their own sketches to decide what features would be best for their team design, and would point to the pin up wall to reference information from the other documents.
2. Both collocated experimental teams used the tag groups to narrow down compare the kickbikes' storage capabilities, one of the groups cross compared storage size to number of wheels total
3. Distributed traditional teams created group folder to compare their own sketches and would verbally guide other team members through the folder hierarchies to the documents they reference to compare to their own sketches.

4. Distributed experimental teams were split in their browsing method, one of the groups used the thumbnail visualization to just browse all files at once without narrowing down documents into groups, while the other group narrow down their browsing images using tag groups. The group that didn't use tags would use the file name and descriptive features of images to guide other team members to the desired image(s).

One of each of the four group types had participants who were observed to provide design feedback by drawing sketch style annotations by the original sketches. This capability, to provide sketched feedback, was also mentioned during user interviews.

User Preferences and Feedback

Participants were asked open ended questions to gain insight on their methods and preferences based on four topics related to tag-based organization; applying tags, searching for documents using tags, saving searches, and additional features that would support the design process. The participants' comments were transcribed and group into five topics that were mentioned by three or more of the sixteen total participants;

- Individual and team organization
- Simultaneous/Collaborative grouping of documents
- Visualization of breakdown of organizing groups
- Predictive/smart search
- Sharing feedback and comments (as a feature of the organization interface)

Table 4.10 shows the results of this grouping.

Table 4.10: Open ended question results

		topic 1	topic 2	topic 3	topic 4	topic 5		
	participant							
colo trad	1	/		/		/		
colo trad	2							
colo trad	3			/		/	**topic 1**	**individual and team organization**
colo trad	4						topic 2	simultanious grouping collaboration
colo exp	5	/					**topic 3**	**visualization of groups overall breakdown (for search)**
colo exp	6			/	/		topic 4	predictive/smart search
colo exp	7			/		/	**topic 5**	**sharing ideas feeback comments (add feature)**
colo exp	8			/*	/			
distr trad	9	/	/	/	/			
distr trad	10	/	/	/				
distr trad	11							
distr trad	12					/		
distr exp	13	/*	/					
distr exp	14	/		/				
distr exp	15	/		/				
distr exp	16			/		/*		
TOTAL		**7**	3	**10**	3	**5**		

Three of these topics were directly requested by at least a third of all participants:

- An additional feature that associates feedback with document organization (31%)
- Allowing both individual and group organization (44% of participants)
- Visualization of the groups created (63%)

Though the results on misunderstanding resolution were less clear than originally intended, the results imply that this tag-based method, though unrefined, is more supportive of the visual browsing and comparing tasks that often occur in the design process.

CHAPTER 5

DISSCUSSION

Though the retrieval test results were not completely in favor of the experimental tag-based method, there are many factors that communicate the potential of tag-based organization in the context of the design process. The qualitative results provided useful insights into the features of tag-based organization that can improve communication between design documents and design team members. Open ended questions showed users receptiveness to features that tag-based organization is capable of provide.

Retrieval Tests

When averaged, the experimental values were higher than the traditional values for both distributed and collocated teams. Though the resultant experimental values were larger there are a couple of factors contributed to the average higher values. The distributed experimental teams had the highest average retrieval value and also had the most tedious procedure for creating tags as a group. Whereas all other teams only had to directly apply whatever tags or folders they wanted to create, the distributed experimental teams needed to use a couple of intermediary software and complete additional indirect steps to be able to share tags as a group due to the fact that Adobe Bridge wasn't designed to easily transfer or share tags between computers. These teams had to take the following steps to create and assign tags between one another:

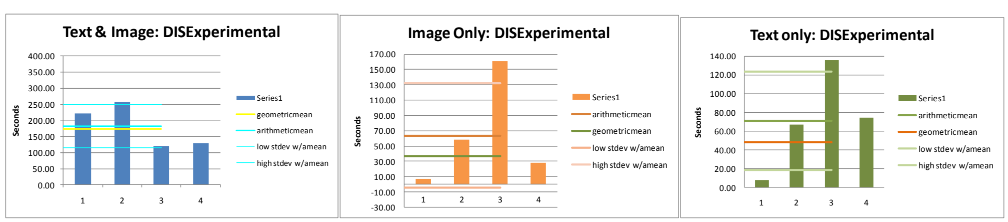
1. Delegated one participant to type all desired tags in to one text file in a text editing program (notebook or Microsoft Word), save the file and send it to all participants via Adobe Connect Now's file uploader.
2. Each of the other participants then cleared the existing tags and

imported the text file with tag names into Adobe Bridge.

3. Once tags were imported Adobe Bridge was closed then reopened for the tags to appear in the keyword window.
4. Team members then had set their windows to the same sort order (by filename or file created value) in order to divide the tags amongst one another to tag. (if team members attempted to tag the same file simultaneously an error would occur and tags applied to that file would be lost).

Secondly, each distributed participant who worked on the computer in one particular room had different technical issues that delayed their ability to collaboratively organize documents and/or design. The participant from the first experimental organization distributed group had their software lag in the midst of retrieval tests, to the extent that the computer eventually had to be restarted for the computer to become responsive again. Table 5.1 shows the resulting consistently higher values for participant 2 in comparison to participant 1 (in same group) in all document retrieval types.

Table 5.1: Distributed experimental retrieval test values



During the second run of the study the participant who also had to work in the same area, was not able to tag any of the documents due to a long delay in loading tag changes to files in Bridge (the organization software used by experimental teams).

In order to find the text and image document, participants were asked to find the document that describes a problem with handlebar storage on a specific type of kick-bike. Thought the document's file name (footbikestorage.pdf) provided a clue to its contents, the question seemed to cause the participants to consistently and incorrectly choose the document which provided the clearest image on the front page of the specific bike asked about (a sales document from the company's website), but not the blog-based opinion document that provided the answer. The confusion between the two documents related to the same bike type may have strongly contributed to the longer retrieval times, but is not unlike document search in the actual design environment.

The extremely short times for traditional teams retrieval of the text only document maybe due to the document's highly informative front page. For this type of document, participants were asked to retrieve anthropometric data for a certain user type. The front page of the correct document is titled "Anthropometric Data", which is clearly visible for the collocated traditional groups who were provided full size printouts of the document, and partially visible for those with digital thumbnails (the words are not as legible in the thumbnail image). The physical document, provided to the collocated traditional groups, was also twice as thick as any of the other documents making it easier to pick out from other documents. With only 45 minutes to review and organize the documents, participants were less likely to evaluate the content of the documents in depth and instead depend upon visual clues from the document as representation of the document's content. This could possibly have caused the longer search times for any of the text-based documents.

The lack of statistically significant difference between experimental and traditional retrieval times is a support for the experimental method because participants of each team using the experimental method were only trained immediately before the designing portion of the study began group. Comparatively, all participants have had at least a minimum two years of experience with the traditional file-folder organization method. Perhaps with more experience with the experimental method the participants could shorten retrieval time considerably. The slightly higher and similar values of distributed teams retrieval times also has a positive result as the method for collaboratively applying tags to design documents was a task participants were not very familiar with before that occasion.

Document Grouping and Cross Categorization

The distributed traditional teams' file copying method for cross categorization had two flaws: all the files in one folder that may apply to other folders are more likely not be put in every appropriate folder, and any files that need updating may be updated in one place but not in the other. Since collocated teams were unable to copy files from one place to another they had to determine what groups were the most important to create advance. None of the collocated traditional teams made changes their pinned up categories perhaps because there wasn't enough time within the 45 minutes to make any organization changes to allow for different comparisons, and all of the 42 documents and images could be seen across a small area even if not in the desired groups to compare by.

Document Comparison and Analysis

The collocated traditional teams, when discussing discrepancies between features desired for their final design, spent their time comparing their sketches for features as opposed to the provided design documents. These actions imply that with constant visibility of documents the users have a tenancy to focus on them less for review since the documents are easily accessible. Distributed traditional teams were less likely to compare design documents and made a separate folder for all of their individual sketches to be held in for easy access. At issue points when documents needed to be reviewed, one participant would take it upon themselves to do the comparison and direct the remaining participants using folder and file names to the document with the tentative explanation of what decision should be made. For example, on team member stressed the importance of small size for folding by first opening the design brief his self and then directing his teammates to where the file was to reaffirm his design requirement. The interface of the traditional file folder system is not thought to be used as a place for document analysis, as all participants using this system would open up whichever file in its default program to evaluate its contents. Due to this fact, participants perhaps weren't as likely to browse documents as opening up several program windows would take up excess screen space and also potentially slow down the computer's performance speed.

Though it was expected for traditional digital teams to have more difficulty browsing specific groups of documents, one of the distributed experimental teams also did not narrow the documents they wanted to evaluate by group. This team browsed all documents at once instead. Admittedly, browsing all documents was most likely just as quick as narrowing down your search group due to the fact there were only 42 design documents, plus whatever small quantity of sketches each team or individual made and uploaded. These 42 documents could be quickly scrolled through as opposed to a larger quantity of documents. The number of documents was not increased to allow time for the participants to actually review the contents of each of the documents.

User Preferences and Feedback

Open ended questioning on user preferences focused on three topics that are common to most design processes: allowing for individual and group organization, visualizations of groups or categories made, allowing for feedback in written and sketch form. As described by Baskin, the product design process requires management of both individual and group design contributions. So as most teams were attempting to balance their own ideas for document groups with those of the group as a whole, they didn't want to lose the information that they'd thought was important individually. This example is best described by a quote from one of the user interviews: "[to] maybe have individual tabs as well as . . . a project tabs so that if you have to take something back and work on a certain part of the project being able to set up your own tags that works best for you and then . . . set up a network . . . where it [your individual tags] updates to the project tabs"

The visualization of the document groups created whether for individuals or groups potentially has two benefits: automatic brainstorming and search navigation. Visibility of all of the design groups that are created can represent a sort of network of what concepts are currently in the scope of the design problem. Allowing access to this visualization during search actually allows the searcher to gauge how deep within their search they may be. The participant verbalized this sentiment while answering the open ended questioning, "I don't really know what sub category, I'm on so I find myself wanting to do a more global search at the time but I'm so far in I don't realize the context of [my] search".

Feedback is a well-established part of the design process. (Lawson 1997) All but one of the distributed teams used the shared whiteboard feature of Adobe Connect Now to suggest changes or clarify features of other designs. Thirty-one percent of the groups requested this feature, and out of that group some referenced the need for sketch-based feedback, like drawings that can be linked to the files they are associated to.

Limitations of study

Understandably, the two hour-three participant design scenario and forty-two design documents used in this study were not the duration or size of those related to an actual professional design cycle; often lasting several months or up to several years and over hundreds of documents. This study focuses primarily on tag-based design document organization and its effects on how distributed and collocated design teams categorize, review and search for design documents , with an additional emphasis on misunderstandings and their resolution. The multidisciplinary groups were intended to bring different perspectives to the design problem similar to that of professional design teams.

The documents provided to the participants were of a variety that would be similar to the contents of a design team in its early stages: inspirational user related images and sketches, textual research documents, as well as hybrid text and image documents. The short time limits imposed on the participants while creating a design solution, were intended to promote development of both expected and unexpected misunderstandings during the design process. The design problem also was selected to require no complex mechanics so that equal input or authority could be given to all participants regardless of their disciplinary background. This study is not intended to evaluate all aspects of the design process so much as to observe in what context document organization potentially influences aspects of the design process.

CHAPTER 6

CONCEPTUAL PROTOTYPE

Analysis resulting from the aforementioned observations and results of open ended questions were used to create design criteria. These design criteria were then used to develop a conceptual prototype built around activities common to most design processes. This section divided into two parts that will describe this process in detail: Design Criteria and Context and Prototype development.

Design Context and Criteria

The design criteria were created from observations and user feedback and divided into topics based on design process activities and context in which they could occur. These activities common to most design processes were derived from <u>How Designers Think</u> (Lawson 1997) and superimposed upon Peng's <u>(Design through Digital Interaction)</u> space requirements as context for the design process. This combination of activities, context, and preferred organization requirements are shown below.

1. Peng's communal visual space as a setting (context) for Lawson's assimilation activity, which involves aggregating and organizing information related to the design topic.

2. Peng's common language requirement for Lawson's general study activity in which deeper study of information and design problem helps team to create rules to guide the features of individual solutions to be aggregated in the next/upcoming phase.

3. Peng's common knowledge base with Lawson's Development/Refinement stage which basically creates a framework composed of multiple rules/constructs that guide the refinement of individual efforts into a few group solutions to be further refined

Figure 6.1 displays the results from mapping user organization preference feedback and observations to the defined design process and its activities.

	1. Assimilation of design documents in a communal visual space	2. Studying design documents to build a common design language between team members	3. Develop a common language base through review of and feedback on designs				
Observations							
Document grouping	x	x					
Cross Categorization of Design Documents	x	x					
Sketched Feedback			x				
Open ended Questions/Interview Results							
Individual and team organization groups	x						
visualizing network of groups		x					
Sharing Feedback as necessary feature			x				

Figure 6.1: Distributed experimental retrieval test values

The design document organization method must be able to support both collocated and distributed multidisciplinary design teams and their process by supporting:

1. a common visual space to allow flexible individual and team level organization of design documents into to multiple groups.
2. a common language by supporting team's ability to visually apply a variety of comparisons between design documents through browsing and collecting these comparisons to share with team or review again at a later time.
3. a common knowledge base by providing feedback capabilities on top of

documents and comparisons as well as flexible viewing between broad and narrow areas of focus and individual and group efforts, so that individual and group solutions can be refined.

A system fitting these criteria would accommodate visual comparisons and annotations of digital design documents. This visual analysis and feedback is common part the design process not supported as well by digital file-folder organization systems and physical pin up walls that can grow out of date from their digital equivalents.

Conceptual Prototype Features

The ultimate goal of all three criteria is to accommodate understanding between team and individual contributions as well as broad and narrow ranges of focus for design information at each stage of the design process. A sample interface is described below in three sections that parallel the design criteria; organization (for document grouping), search (for document browsing and comparison) and feedback (evaluating how design parts fit in a group design and vice versa). Each section provides a design process context and description of interactions for the refined organization interface within the design context.

Collaborative and individual grouping of design documents

In the earlier stages of the design process, design teams will collect both general and specific information on a design problem to get a clearer understanding of the resultant design (Lawson 1997).These documents will range from being more general in nature like photographs to more specific, i.e. complex technical specifications of existing products. Co-located groups will often distribute ideas derived from these documents across large surfaces to map out broad understanding of the various details that compose this design problem.

From the open ended questioning, some participants were satisfied with the experimental software's (Adobe Bridge) method of viewing and assigning tags to documents: document and checkbox selection. Others preferred a more visual method, though they weren't specific as to how. In order to accommodate both visual and textual methods of information processing, the tags will be presented solely as text in one space and graphically in another (shown in Figure 6.2). The organization interface would be required to handle both individual and team document organizations. Each individual's space would contain images of the documents assembled on a plane or a wall, but the group visualization would assemble the walls into a larger assembly of planes to represent the group's organization. Figure 6.3 shows how the interface could provide visualization to clearly transition between individual and team tags. Once in "team tag mode" both individual and group tags will be available during group tag visualization. Group and individual tags will be given different appearances, as presented in Figure 6.4. The group tag creation will be supported by data collected from individual tag creation and team members linking design documents to one another, such that tags can be suggested by the system, referencing tags common to individuals within the team (shown in Figure 6.5). The hierarchy and interrelation of tags applied would be retrieved from file information and provided as visualization. This visualization of tags would provide a mapping of terms useful for brainstorming and affinity diagramming stages in the design process and also help to see the differences in collective and individual frameworks of the design problem.

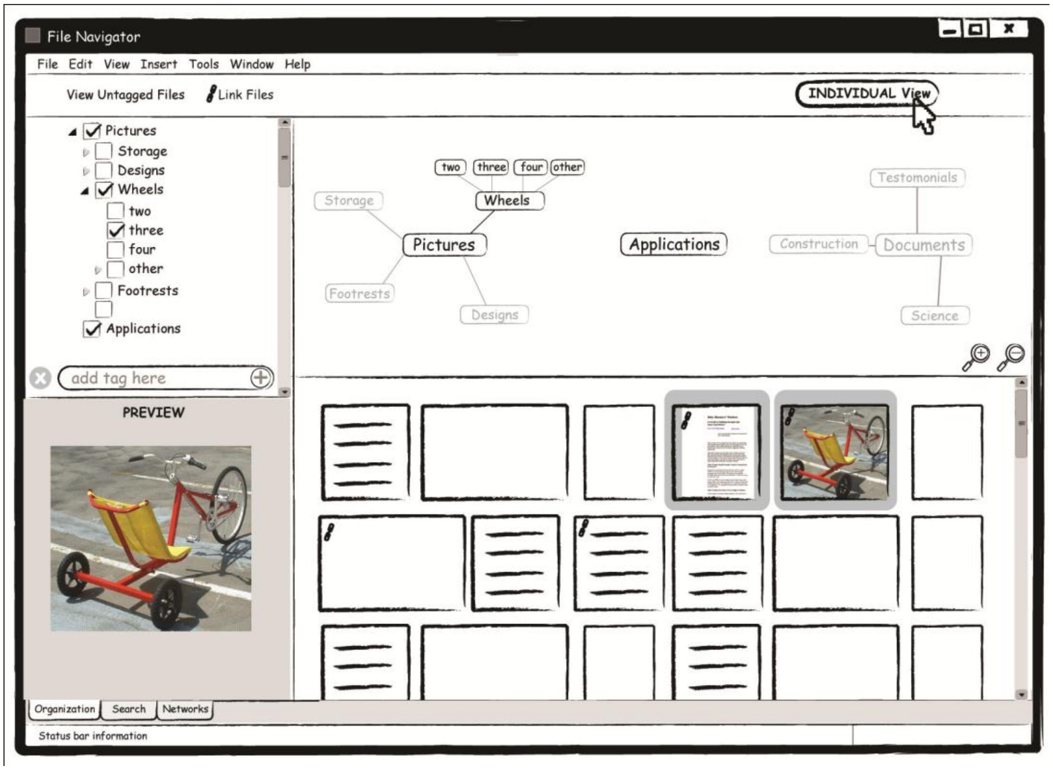


Figure 6.2: Conceptual interface with individual tag network visualization (top right) and text only tag space (top left)

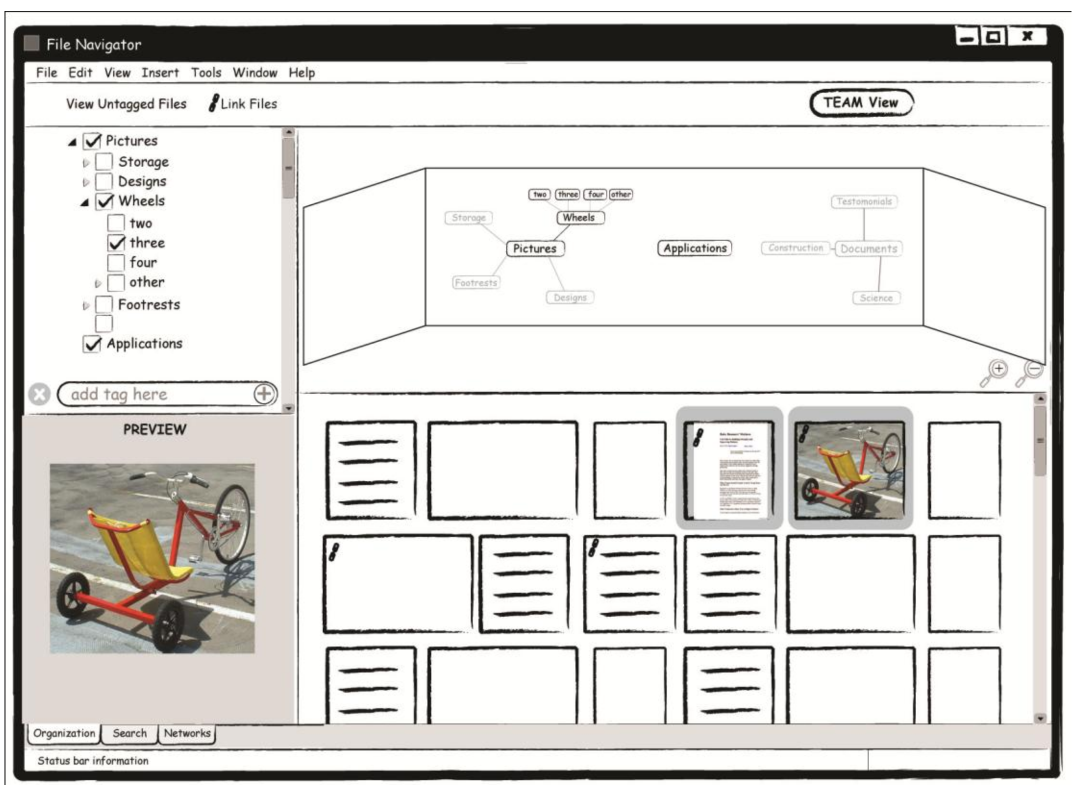


Figure 6.3: Conceptual interface with individual to team tag transition visualization

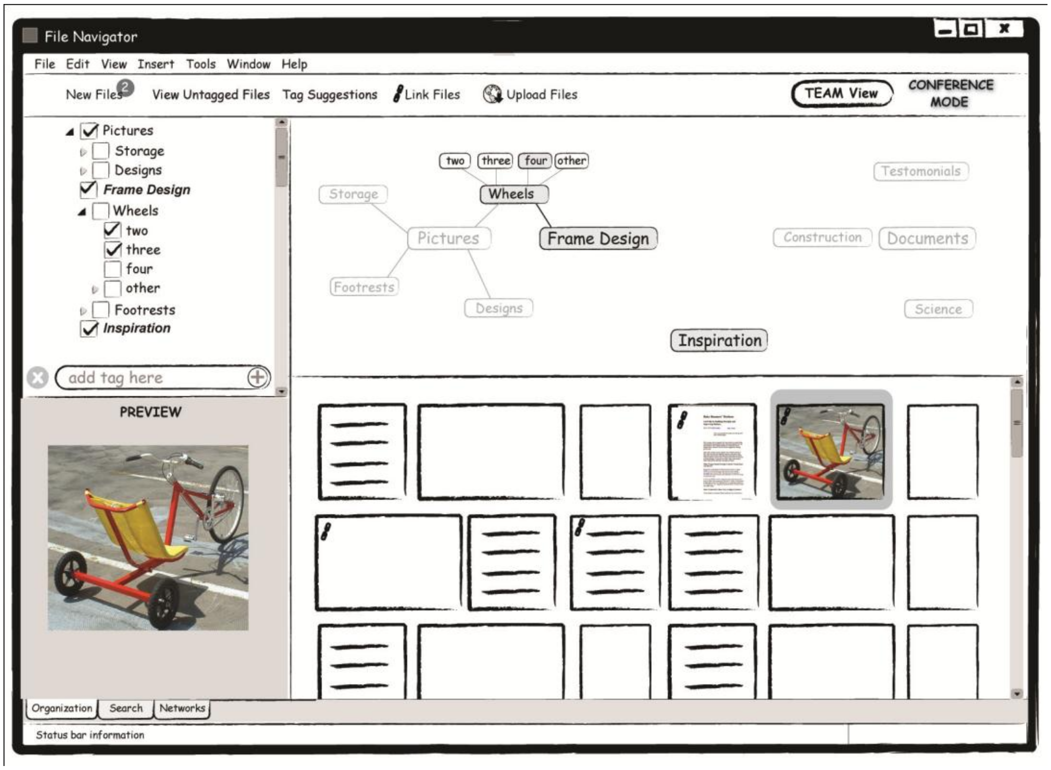


Figure 6.4: Conceptual interface with individual and group/team tag network visualization

Figure 6.5: Conceptual interface with linked files and group tag prediction prompt

<u>Tag Search and Browsing</u>

Once these documents are organized, team members begin to collect a broad range of individual design concepts to compare and narrow to develop requirements and features that are needed for the design solution. Within the search part of the interface, the organization system would support this activity by allowing multiple and hierarchical tag browsing, searching and comparing of design documents. Team members would able to narrow in on the documents they're looking using two methods: a textually-based list that allows search requirements to be populated similar to a product searching list on an online store; and a visually-based tag search; with "must have", "must not have", and "either or" *buckets* to drag tags into. A search bar for tag names will intelligently propagate tags requiring only partial spelling of the tag and displaying tags frequently used by other team members first. Searches or file groups that maybe used frequently could then be saved like bookmarks. In this search version of the overall interface, visualizations of the network of files linked to the retrieved document are available during tag-based document search. This feature will help its users to see what other files will be affected by changes to the retrieved document. These features can be seen in Figure 6.6.

Figure 6.6: Conceptual interface in search mode

<u>Feedback and flexible visualization of document groups</u>

In order to form the set of rules that define the solution space (from Peng described in Chapter 2), each individual member needs to understand the problem as a whole and also with respect to their individual contribution to the solution. This understanding is built from feedback between team members. The Networking part of the system, shown in Figure 6.7, allows flexible viewing of design documents, broadening and narrowing focus per the direction of its user, but it will also provide a visualization of contributions to a design document per discipline (or section of design team) to support understanding of how their design parts interrelate. The comments of the study participants guided the addition two methods of feedback for the design documents. As shown in Figure 6.8, Text comments would initially be seen as a mini post it notes in the top corner of annotated document's thumbnail. Sketch over notes, where the person annotating is actually drawing notes and pictures over top the original document, will be represented as a pencil icon in the opposite corner of this thumbnail and is shown in a preview space when selected. This sketch would also be saved as a separate file that is permanently linked to the original base file.

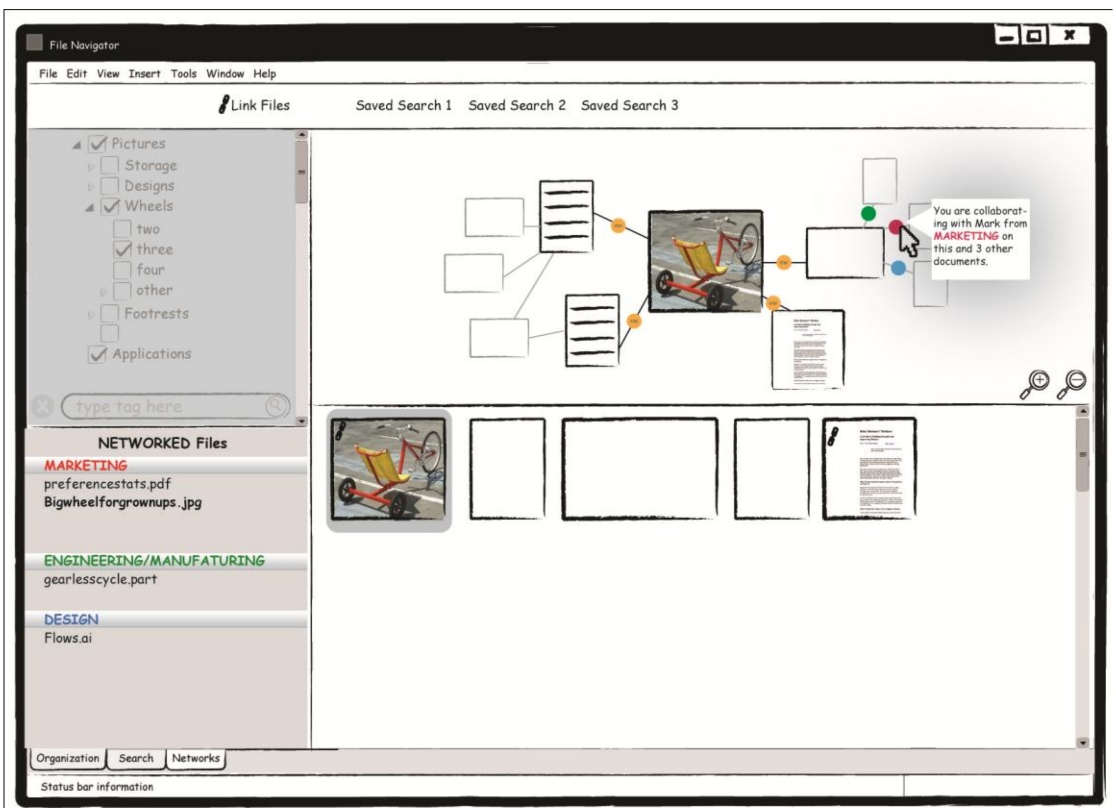


Figure 6.7: Network feature of conceptual interface in Network mode

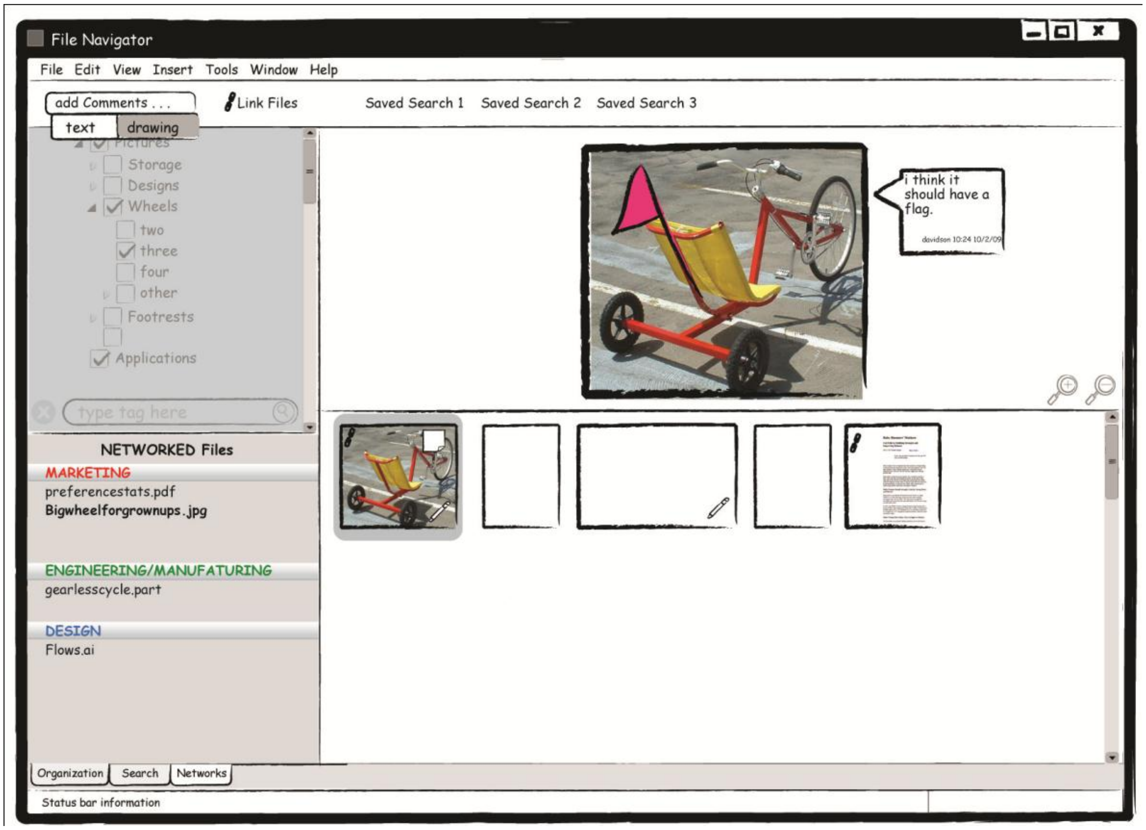


Figure 6.8: Feedback feature of conceptual interface in Network mode

CHAPTER 7

CONCLUSION

Research Goals

Tag-based organization's superior potential for cross categorizing, comparing and analyzing visual design documents is supported in the results of this study. On the other hand participants, though receptive to tag-based organization, saw this method as a support or backup to the folder method. Lack of experience and training with this method was not the only issue hindering higher acceptance of this method. The tag-based software poorly supported the need for hierarchies, one of the primary benefits of folder-based organization methods. Although the surrogate tag-based organization interface, Adobe Bridge, allows its users to create a hierarchy of tags, this hierarchy is not visible during tag-based document search. Perhaps with the hierarchy left visible, as suggested in the conceptual interface, users would be more apt to accept the tag-based method in isolation than as a supplement to the file folder method.

The organizing groups between individuals and their teams will differ and users are not as comfortable with changes being made when one person applies these changes to team files others are not aware of it. In contrast to the static file-folder method, the conceptual interface's prompt windows for handling tag evolution and changes could also be useful for managing conflicts within the design team. The notifications the interface would provide would allow them an additional vehicle for understanding and addressing how their individual areas of focus (represented by tag terms and networks) in the design problem fit into their teams overall goals and requirements, potentially supporting misunderstanding resolution on an individual level.

Recommendations and Future Work

Though the primary user recommendations were cross categorization between topics as well as individuals and team, visualizations of organizing groups, and sketch feedback capabilities, there were a few additional features were extrapolated from observations. The need for reviewing past documents and looking back for missed insights or refining the design problem or changing the direction a design solution is headed occurs in nearly every design process (Baskin, Kovács et al. 1999). Tag-based organization, by allowing the users to apply a variety of structures to a document, could provide teams better access to ideas as areas of focus their design process evolve and change. Further study would include a more realistic long term design simulation with several sessions and additional opportunities for individual grouping of documents, design focus redirections and larger quantities of both individually and team contributed design documents.

A secondary but important potential benefit to this organization method is its capabilities as a term, concept, and network visualization tool. The interfaces potential ability to allow its users a visual representation of the current structure of tags, documents, and disciplines at any given time in the design process is potentially a very powerful feature for the design process. This feature would be most beneficial for distributed teams, by allowing those not capable of accessing a physically shared design space to have access to the same visualization of interrelated aspects of the design problem as a collocated team and potentially more flexibility to change those visualized structures. Further research could test the relationship between such visualizations and information shared between distributed design teams.

APPENDIX A

DESIGN BRIEF

Design Scenario: Short Distance Wheeled Transporation

Background

-35-55 year old females
-lives in small, fairly flat city (2-4 square miles) with mainly local small businesses
-will make stops to local markets and stores in city center every two to three days
-Participates bi-weekly in crafts and other classes in city (e.g. ceramics, knitting and pilaties, yoga)

Requirements

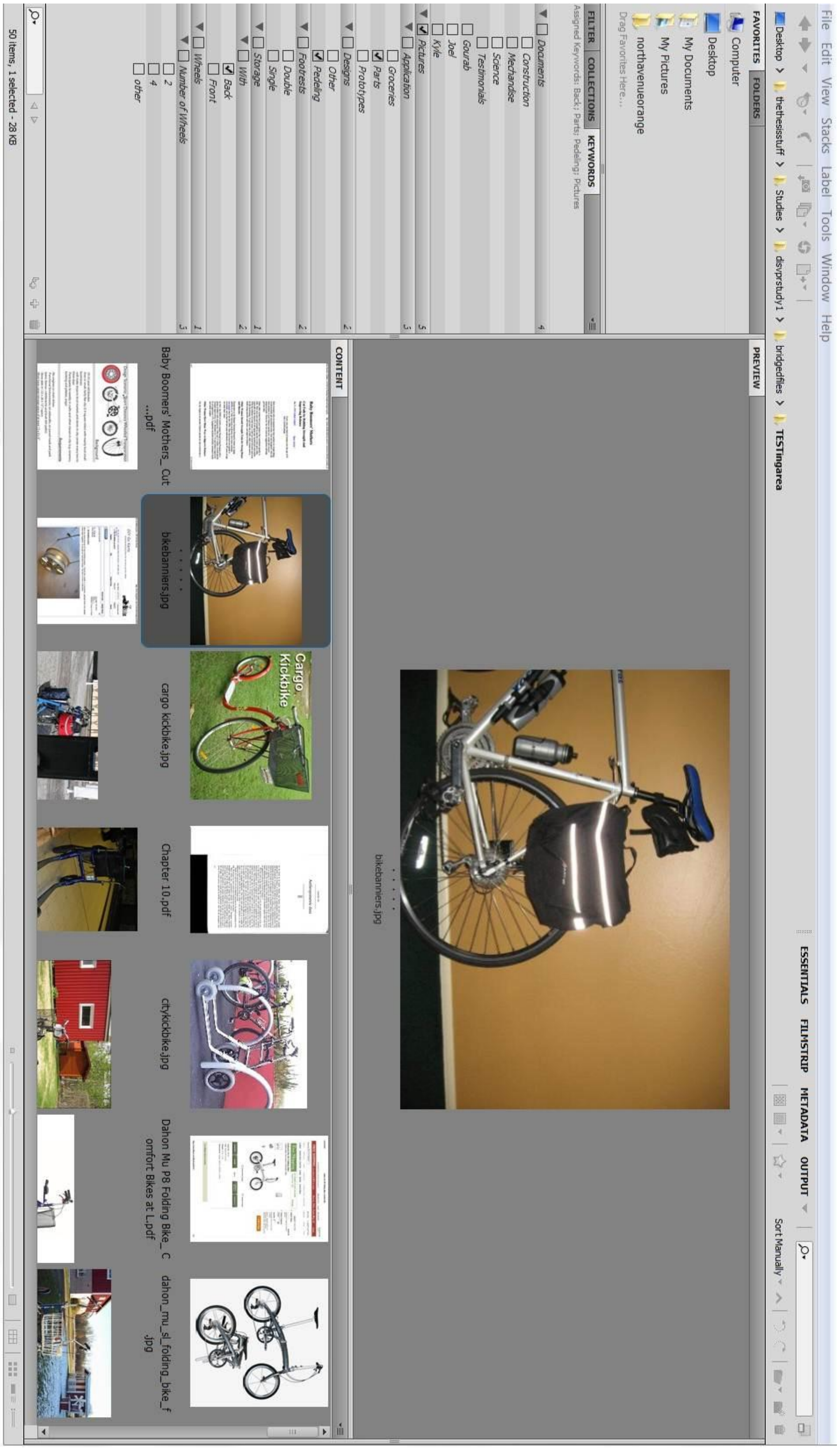
-No engines or chain drives
-Functional Environments: on sidewalks, on paved roads and park lawns (bonus: cobblestone and level dirt paths)
-Stow-able in (32 x 26 x 12") space
-Must have cargo/storage space of at least 13 x 9 x 9"

Deliverable

11 x 17 pg document (template provided)
-basic dimensions
-proposed materials for manufacture
-feature descriptions and context of use for each feature

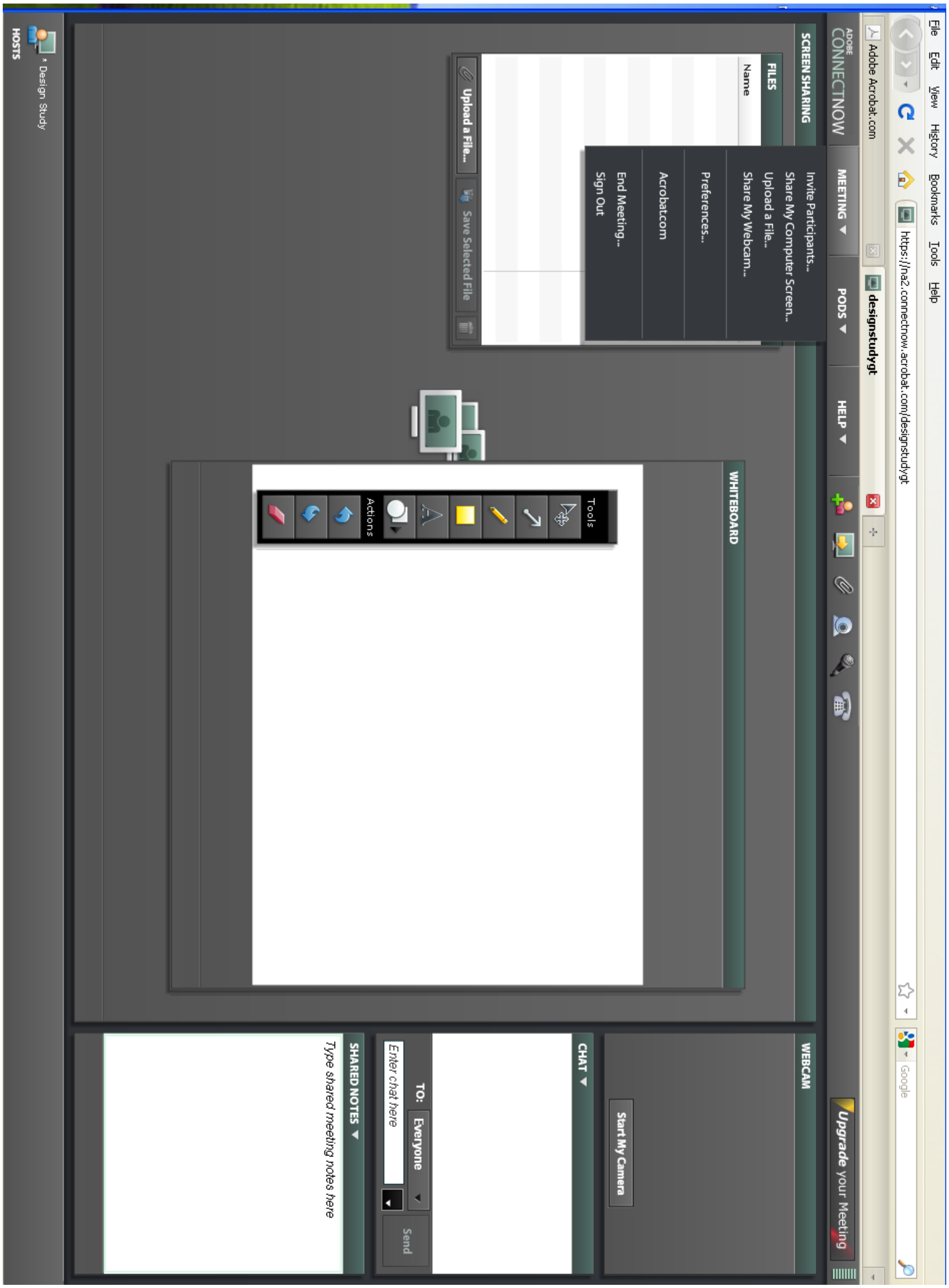
APPENDIX B

ADOBE BRIDGE INTERFACE



APPENDIX C

ADOBE CONNECT NOW INTERFACE



APPENDIX D

USER FEEDBACK QUESTIONS

Individual interview questions:

1. Recalling the method that you just took to create tags, what computer actions would you like to take to add tags to files (individually vs in a group)? Remove tags from files? Share tags with others? Share tag search results?
2. Are there any other features you think this organization system should have?

About the collaborative tagging experience:

3. How did the tags you wanted apply to the files differ from what your teammates chose?
4. Thinking of the last long term design project you had for a class, how comfortable would you feel using this system as opposed to a file and folder system to organize your files (on a project you are working on alone/ in a group)?

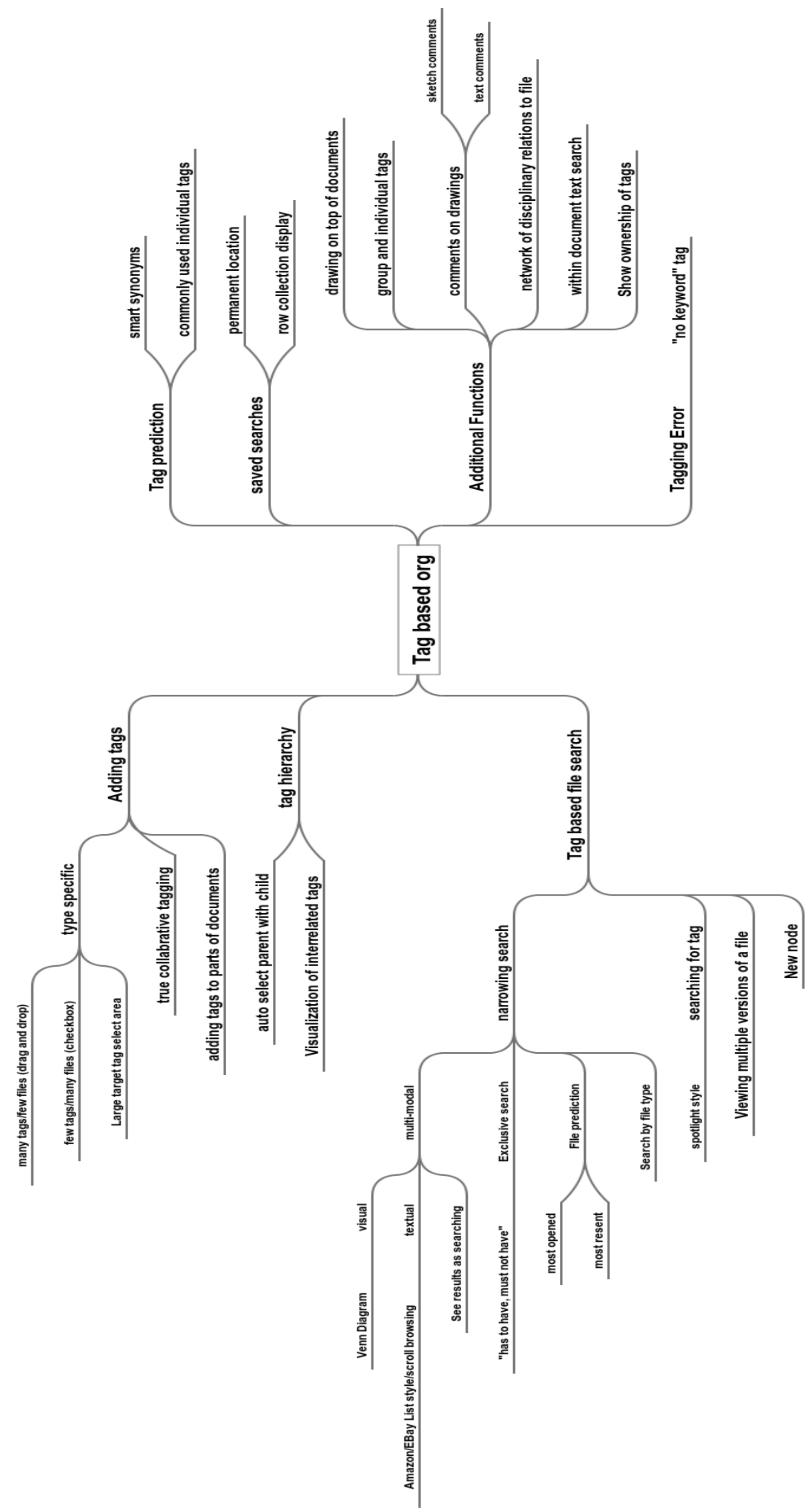
Group interview questions:

1. How well do you think the content thumbnail images help you to find to the file you needed?
2. How well do you think the tag-based organization/file folder organization help you to get to the file you needed?
3. Reflect on the work your team did during both the tagging and designing portion of this study were there any other issues (or different methods/ways of searching or organizing) that you'd like the organization system to handle?

4. Are there any additional features you think the organization system should have to help your teams design process?
5. Were there any specific types of documents or files that were more difficult to find using this particular organization system?

APPENDIX D

MAP OF USER PREFERENCES



APPENDIX E

DOCUMENT ORGANIZING GROUPS

Traditional Document Organization

Collocated

- Container/Basket
- Number of user
- Wheels type
- Transportation
- Fun & Leisure
- Style
- Folding
- DIY/Customization
- Poses that prevent falls related product of yoga
- Improvement feature of transportation

- Cargo
- Single Kick
- DIY
- Folding Bike
- Bike with chains
- Cargo Carriers
- Double kickbike
- Double kickbike & Cargo
- Single kickbike
- Single kickbike & Cargo

Distributed

- Fabrication
- Research
- Storage
  - front
  - other
  - rear
- Wheels
  - 2 wheel frame
  - 3wheel frame
  - 4 wheel frame
  - four
  - other
  - two

- Documents
  - DIY instructions
    - Folding Bikes
    - Kick Bikes
  - Research Data
    - Footbike
    - Medical Research
    - Yoga
  - User Reviews
- Images
  - Folding
  - Purpose
    - Fun
    - Transport
  - Storage
    - Front storage
    - Rear storage
    - Other
  - Wheels
    - 2Wheels
    - 4 Wheels
    - other
- Our sketches

Experimental Tag Document Organization

Collocated

- Body Positioning
  - sitting
  - standing
- Child Seat
- Documents
  - commercially available designs
  - DIY
  - medicals
- Foldability
- Locomotion Mechanism
  - Kick
    - Double
    - Single
  - Pedal
- Storage
  - Bag
  - Basket
- Wheels
  - 2 wheels
  - 3 wheels
  - 4 wheels

- Activities
- Anthropometry/Biomechanics
- Features
  - 2-wheeler
  - 3-wheeler
  - 4-wheeler
  - carrying space
  - chain-drive
  - double foot platform
  - foldable
  - kick-drive
  - seat
  - single foot platform
- Reviews
- Sample Projects
- Tech Specs

Distributed

- Demographics
  - Adult
  - Kid
- Novelty
  - low seat
  - no seat
  - stability
- Purpose
  - cargo
  - Fun
  - locomotion
  - portability
- Storage
  - amount
  - back mounted
  - front mounted
- Wheels
  - big front
  - four wheels
  - three wheels
  - two wheels

- Documents
  - Constructions
  - Merchandise
  - Science
  - Testimonials
- Particpant1
- Particpant2
- Particpant3
- Pictures
  - Application
    - Groceries
    - Parts
    - Prototypes
  - Designs
    - Other
    - Pedaling
  - Footrests
    - Double
    - Single
  - Storage
    - With
      - Back
      - Front
  - Wheels
    - Number of Wheels
      - 2
      - 4
      - other

REFERENCES

Baskin, A. B., G. Kovács, et al. (1999). Cooperative knowledge processing for engineering design. Norwell, Mass., Kluwer Academic Publishers.

Brandl, P., M. Haller, et al. (2008). Bridging the gap between real printouts and digital whiteboard. Proceedings of the working conference on Advanced visual interfaces. Napoli, Italy, ACM**:** 31-38.

Busby, J. S. (2001). "Error and distributed cognition in design." Design Studies **22**(3): 233-254.

Chung, E. Y., J (2009). "Categorical and specificity differences between user-supplied tags and search query terms for images: an analysis of Flickr tags and Web image search queries." nformation Research **14**(3): 408.

Creswell, J. W. (1998). Qualitative inquiry and research design : choosing among five traditions / John W. Creswell. Thousand Oaks, Calif. :, Sage Publications.

deRosa, D. V. and S. Tkacz (1976). "Memory scanning of organized visual material." Journal of Experimental Psychology: Human Learning and Memory **2**(6): 688-694.

Dijk, L., J. S. M. Vergeest, et al. (1998). "Testing shape manipulation tools using abstract prototypes." Design Studies **19**(2): 187-201.

Fjeld, M., K. Lauche, et al. (2002). "Physical and Virtual Tools: Activity Theory Applied to the Design of Groupware." Computer Supported Cooperative Work (CSCW) **11**(1): 153-180.

Giordano, D. (2002). "Evolution of interactive graphical representations into a design language: a distributed cognition account." International Journal of Human-Computer Studies **57**(4): 317-345.

Golder, S. A. and B. A. Huberman (2006). "Usage patterns of collaborative tagging systems." Journal of Information Science **32**(2): 198-208.

Haller, M., P. Brandl, et al. (2006). Shared Design Space: Sketching Ideas Using Digital Pens and a Large Augmented Tabletop Setup. Advances in Artificial Reality and Tele-Existence. Z. Pan, A. Cheok, M. Halleret al, Springer Berlin / Heidelberg. **4282:** 185-196.

Halverson, C. A. (2002). "Activity Theory and Distributed Cognition: Or What Does CSCW Need to DO with Theories?" Computer Supported Cooperative Work (CSCW) **11**(1): 243-267.

Hinds, P. J. and D. E. Bailey (2003). "Out of Sight, Out of Sync: Understanding Conflict in Distributed Teams." ORGANIZATION SCIENCE **14**(6): 615-632.

Hsieh, W.-T., J. Stu, et al. (2009). "A collaborative desktop tagging system for group knowledge management based on concept space." Expert Systems with Applications **36**(5): 9513-9523.

Hutchins, E. (1995). Cognition In the Wild. Cambridge, Mass, MIT Press.

Isabella Peters, W. G. S. (2010). "“Power tags” in information retrieval." Library Hi Tech **28**(1): 81-93.

Joho, H. and J. M. Jose (2008). "Effectiveness of additional representations for the search result presentation on the web." Information Processing & Management **44**(1): 226-241.

Jonson, B. (2005). "Design ideation: the conceptual sketch in the digital age." Design Studies **26**(6): 613-624.

Keller, I., F. Sleeswijk Visser, et al. (2009). "Collecting with Cabinet: or how designers organise visual material, researched through an experiential prototype." Design Studies **30**(1): 69-86.

Khan, A., J. Matejka, et al. (2009). "Toward the Digital Design Studio: Large Display Explorations." Human–Computer Interaction **24**(1): 9 - 47.

Klemmer, S. R., K. M. Everitt, et al. (2008). "Integrating Physical and Digital Interactions on Walls for Fluid Design Collaboration." Human–Computer Interaction **23**(2): 138 - 213.

Klemmer, S. R., M. W. Newman, et al. (2001). The designers' outpost: a tangible interface for collaborative web site. Proceedings of the 14th annual ACM symposium on User interface software and technology. Orlando, Florida, ACM**:** 1-10.

KristjÃ¡nsson, A. (2000). "In search of remembrance: evidence for memory in visual search." Psychological Science: A Journal Of The American Psychological Society / APS **11**(4): 328-332.

Kvan, T. (2000). "Collaborative design: what is it?" Automation in Construction **9**(4): 409-415.

Lai, I.-C. and T.-W. Chang (2006). "A distributed linking system for supporting idea association during the conceptual design stage." Design Studies **27**(6): 685-710.

Lauche, K. (2005). "Collaboration Among Designers: Analysing an Activity for System Development." Computer Supported Cooperative Work (CSCW) **14**(3): 253-282.

Lawson, B. (1997). How designers think : the design process demystified. Oxford ; Boston, Architectural Press.

Lee, S., W. De Neve, et al. "MAP-based image tag recommendation using a visual folksonomy." Pattern Recognition Letters **31**(9): 976-982.

Li, W. D. (2007). Collaborative product design and manufacturing methodologies and applications. London, Springer.

Ling, T., C. Jizhong, et al. (2007). CoDesign Space: a collaborative design support system in a network environment. International Journal of Computer Integrated Manufacturing, Taylor & Francis Ltd. **20:** 265-279.

Lloyd, P. and P. Deasley (1998). "Ethnographic description of design networks." Automation in Construction **7**(2-3): 101-110.

McKim, R. H. (1980). Experiences in visual thinking. Monterey, Calif. :, Brooks/Cole Pub. Co.

Miettinen, R. and M. Hasu (2002). "Articulating User Needs in Collaborative Design: Towards an Activity-Theoretical Approach." Computer Supported Cooperative Work (CSCW) **11**(1): 129-151.

Paivio, A. B., IAN (1974). "Pictures and words in visual search." Memory & Cognition **2**(3): 7.

Peng, C. (2001). Design through digital interaction : computing communications and collaboration on design. Bristol, England ; Portland, Or., Intellect.

Perry, M. and D. Sanderson (1998). "Coordinating joint design work: the role of communication and artefacts." Design Studies **19**(3): 273-288.

Quan, D., Bakshi, K., Huynh, D., Karger, D. R. (2003). User Interfaces for Supporting Multiple Categorization. Interact 2003—ninth IFIP TC13 international conference on HCI. M. R. e. al., IOS Press**:** 228–235.

Rea, M. (2009). "Sketchy Illustrator wireframes." Retrieved May 31, 2010, from http://matthewrea.com/07.21.09/Sketchy-Illustrator-wireframes/41.php.

Robin, V., B. Rose, et al. (2007). "Modelling collaborative knowledge to support engineering design project manager." Computers in Industry **58**(2): 188-198.

Rorissa, A. (2008). "User-generated descriptions of individual images versus labels of groups of images: A comparison using basic level theory." Information Processing & Management **44**(5): 1741-1753.

Rorissa, A. and H. Iyer (2008). Theories of cognition and image categorization: What category labels reveal about basic level theory. Journal of the American Society for Information Science & Technology, John Wiley & Sons, Inc. / Business. **59:** 1383-1392.

Sauro, J. and J. R. Lewis (2010). Average task times in usability tests: what to report? Proceedings of the 28th international conference on Human factors in computing systems. Atlanta, Georgia, USA, ACM.

Woodruff, A., R. Rosenholtz, et al. (2002). "A comparison of the use of text summaries, plain thumbnails, and enhanced thumbnails for Web search tasks." Journal of the American Society for Information Science and Technology **53**(2): 172-185.

Xu, Z., Y. Fu, et al. (2006). Towards the semantic web: Collaborative tag suggestions. Proceedings of Collaborative Web Tagging Workshop at 15th International World Wide Web Conference.

Zager, D. (2002). "Collaboration as an Activity Coordinating with Pseudo-Collective Objects." Computer Supported Cooperative Work (CSCW) **11**(1): 181-204.